ACTA RADIOLOGICA
EDITA IUSSU SOCIETATUM RADIOLOGICARUM
DANIAE, FENNIAE, NORVEGIAE ET SUECIAE

VOL. 47 JUNE 1957 FASC. 6

ORBITOGRAPHY WITH WATER-SOLUBLE CONTRAST MEDIA

by

G. Lombardi

The attempts at orbitography by means of contrast media, which began in 1927, are justified by the difficulties encountered in diagnosing retrobulbar neoformations — either clinically or radiologically.

Several substances used in the past for orbitography (Thorotrast, Lipiodol, etc.) have been abandoned one after the other because they were found to be injurious or unsuitable. At present the choice is confined to the gaseous (air, oxygen, etc.) or water-soluble contrast media. The first-named are still preferred by most authors. We ourselves however, after a long experience, have arrived at the conclusion that the images obtained with gaseous contrast media often lead to uncertain or erroneous interpretations, even when studied by means of tomography. For these reasons we have, since 1953, been carrying out orbitography with water-soluble preparations.

The injection of the contrast medium may be made into the episcleral space or into the muscular conus. The former serves for delimiting the eyeball and its uses are somewhat restricted (KATZ and LEDOUX, MANCHESTER et coll., PETTINATI, et al.); the latter injection permits the exploration of the retrobulbar space and is indicated for investigations of tumours and pseudo-tumours of the orbit. The material for the present study consists of fifty orbitographies belonging to the second group.

Technique. The technique suggested in Italy by MONTRESOR (1952), MAZZI, CHINAGLIA & SANTELLI has been used. It differs only in minor details from the technique described in turn by COWIE & GROVES, MANCHESTER et coll., et al.

As contrast media, 3 ml Umbradil 35 % or equivalent preparations

Submitted for publication 15 October 1956.

From the Roentgen Department of the Ophthalmic Institute (Director: C. Galeazzi) and from the Neurologic Institute (Director: G. Vercelli), Milan, Italy.

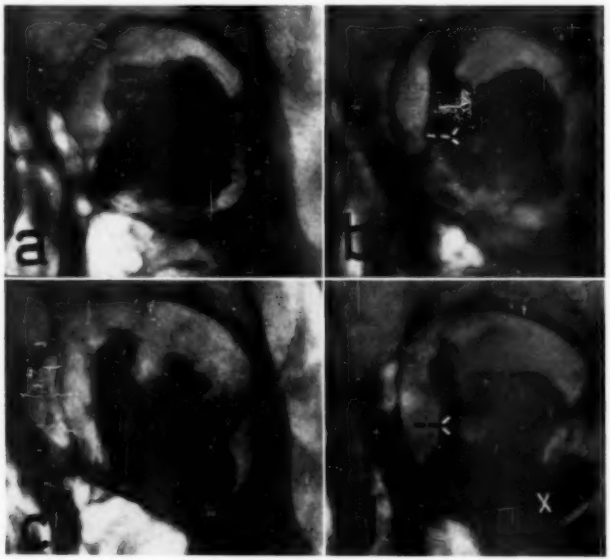


Fig. 1 a—d. Normal orbitographies. b) and d) Optic nerve indicated by - - <; at x a little contrast medium has escaped from the muscular conus.

(diodrast, diodone, Joduron, etc.) are used but as at this concentration the iodide preparation can still injure the tissues and structures of the orbit (MANCHESTER, BONMATI et coll.) it is diluted by the addition of 1 ml Novocaine 4 % and about 100 units of Hyaluronidase dissolved in 1 ml of distilled water. The result is a final concentration of about 21 %, which still gives good contrast. As a matter of fact, the experimental research carried out by COWIE & GROVES has demonstrated that the minimum concentration of iodide solutions utilizable in orbitography is 17 %.

The solution, prepared as above, is injected into the muscular conus, using the ordinary technique of retrobulbar anesthesia. In normal subjects, the quantity of fluid injected varies from 3 to 5 ml, according to the resistance felt by the operator; in cases of pathologic lesions the quantity should of course be reduced to suit each one individually. Having withdrawn the needle and applied a slightly compressive bandage, films should be taken in p. a. and lateral projections. According to the first results obtained, complementary views may be advisable, but it must be borne in mind that the contrast material is rapidly resorbed and disappears within 15 minutes.

After the injection some of the patients complain of retro-ocular

tension, which only a few find intense and which spreads to the forehead and occiput. After 10 to 20 minutes oedema of the conjunctiva and eyelids usually appears and lasts a few hours.

In some of our cases and those described in the literature complications have arisen. In two of our patients who suffered intense pain, vomiting, and nausea, it was observed that part of the preparation had passed into the subdural spaces of the cranium (Fig. 7). In these cases too, however, the acute initial symptomatology slowly diminished and disappeared after a few hours without after-effects. The possibility of this complication has also been pointed out by GIFFORD. MANCHESTER & coll. have observed in one patient whose visual function was intact that perception of light disappeared for about 15 minutes, this returning to normal again after 26 hours.

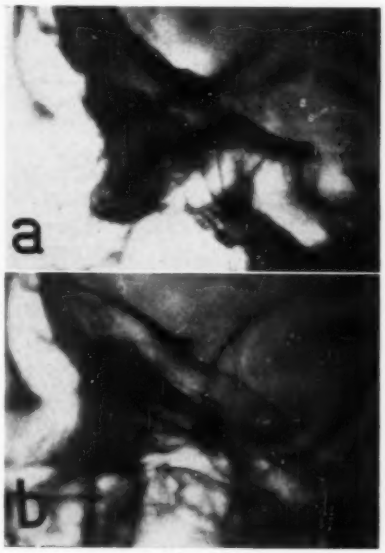


Fig. 2 a—b. Normal orbitographies: Muscular conus in lateral views.

Normal orbitography. In the p. a. projection, when large quantities of contrast media have been injected into the muscular conus, and especially when this has accumulated behind the eyeball (MAZZI), the conus has a rounded appearance, intensely opaque, and situated in the centre of the orbit (Fig. 1 a). With smaller quantities (3 to 5 ml) — as are always advisable in practice — the image of the conus may be compared to three- or four-leaved clover, according to the number of indentations which appear along its supero-external border (Fig. 1 b, c, d). The indentations correspond to the impression of the extraocular muscles and the so-called folia to the spaces which protrude between the muscular fascia. In the infero-medial section of the conus the image of the optic nerve is often recognizable, seen in section (Fig. 1 b, d). In the lateral projection a faithful reproduction of the 'muscular conus' may be observed (Fig. 2).

The projections described are fundamental for diagnostic purposes although some writers consider it advisable to carry out the special optic foramen projection.

Orbitographic experience has shown that even when the retrobulbar

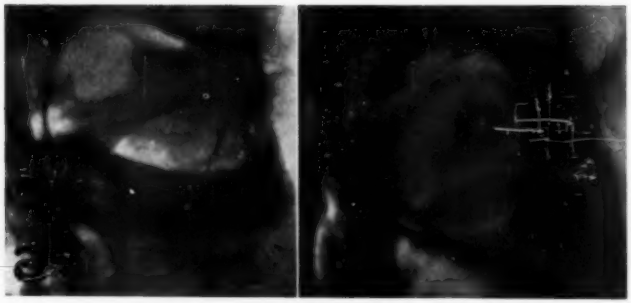


Fig. 3. Escape of contrast medium from muscular conus.

injection is made by experienced operators the contrast medium is often injected outside the muscular conus or escapes from the latter. Outside the muscular conus the water-soluble preparation tends to flow rapidly towards the eyelids, which have already become swollen during the injection. The roentgenograms confirm its distribution in the peripheral parts of the orbit, showing typical images, which however cannot be used for diagnostic purposes (Fig. 3). In such cases the investigation should be repeated after a few days, as soon as the condition of the orbit permits.

Even when the injections are correctly carried out, a few drops of contrast medium usually flow back to the outside of the conus along the path of the needle, but without compromising the results of the examination (Fig. 1 d).

Of the 50 retrobulbar orbitographies so far carried out, 15 have failed or could not be used because the contrast medium ran out of the muscular conus; 16 were negative and 19 positive. A large part of these failures date from the first attempts.

Pathologic orbitography. All the 19 patients in whom the examination gave a positive result were affected with unilateral exophthalmus. There were 11 primary tumours and 4 pseudo-tumours of the orbit, which were all operated on and examined histologically. The remaining 4 cases of pathologic orbitography have not been taken into account because of the lack of operative control.

The tumours and pseudo-tumours are discussed together, because, according to our experience, it is not possible to differentiate between them by orbitography. These neoformations reveal themselves in various ways according to their volume, their position in the orbit, and their effects upon the surrounding tissues. The images observed are the following:

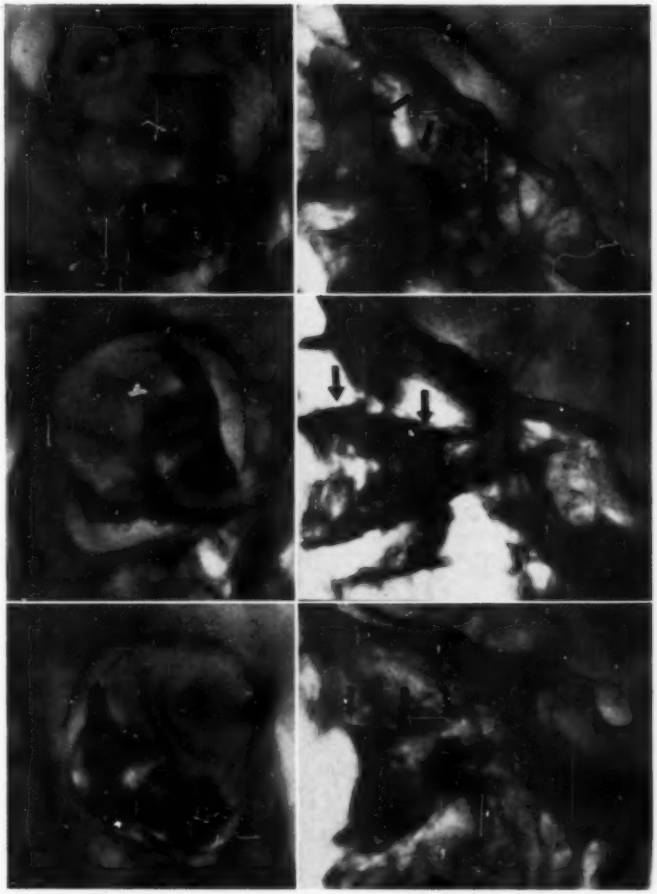


Fig. 4 a) Cavernoma the size of an almond, removed transfrontally. Deep neoplasm of supero-external section of orbit, situated under upper rectus muscle. b) Lymphosarcoma of supero-external section of orbit, removed partially by orbitotomy. c) Basaloma, the size of an almond, situated in supero-external section of orbit; the neoplasm was removed completely by Krönlein's operation.

a) The impression on the muscular conus rendered opaque (10 cases; Figs. 4 and 5);
b) Amputation of part of the conus (1 case; fig. 6);
c) Distribution of the contrast medium around the lesion (4 cases; Figs. 7 & 8).

Only the last item requires some comment. The roentgenographic appearances observed in these cases are almost identical with those seen following episcleral injections, differing only as regards position and shape. The anatomic conditions are also practically identical in the two cases, because, during the operation, tumours and pseudo-tumours were found to be clearly defined. The contrast medium could therefore

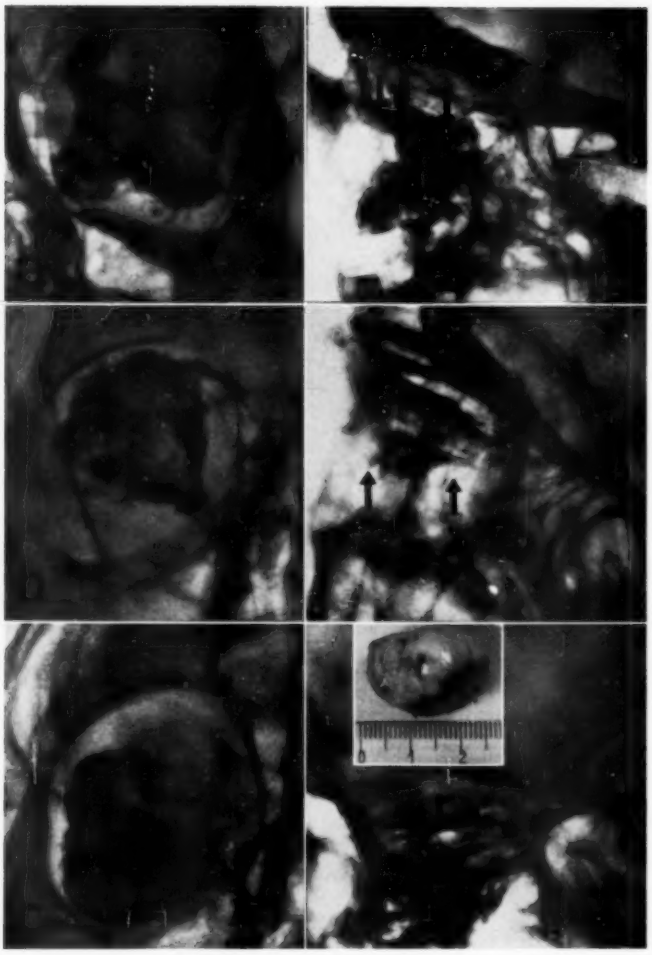


Fig. 5 a) Basaloma, the size of an almond, situated in supero-external section of orbit; removed completely by Krönlein's operation. b) Basaloma in infero-external section of the orbit, removed partially by Krönlein's operation. c) Deep fasciculated neurinoma, situated under upper rectus muscle, removed transfrontally.

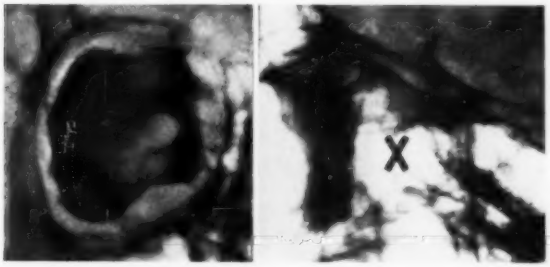


Fig. 6. Deep cavernoma, removed transfrontally. Typical example of the amputation of the muscular conus apex (x).

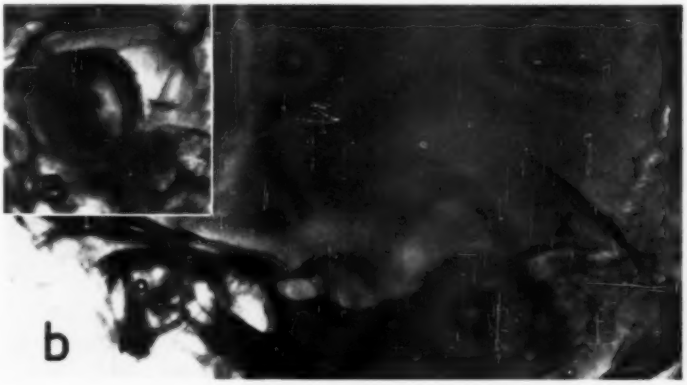


Fig. 7. Deep fasciculated neurinoma, removed completely transfrontally. a) Neoplasm delimited peripherally by contrast medium (p. a. projection). b) Deep site of neoplasm (o). It is partially delimited by the contrast medium, which has also penetrated inside the cranium spreading along the underside of the tentorium (x).

spread itself in the virtual space surrounding the mass with a progression evidenced by serial roentgenography (Fig. 8).

From the practical point of view it is advisable to sub-divide the endo-orbital neoformations into 'superficial' and 'deep'.

In the case of palpable *superficial neoplasms* appearing at the contour of the orbit, orbitography is indicated simply for ascertaining their development in depth for the purpose of selecting the most suitable form of operation. This can be decided by means of lateral projections, the reading of which is often difficult owing to the slender evidence offered by the images. In our opinion, the importance of obtaining precise information is such as to justify the repetition of the investigation every time any doubt remains.

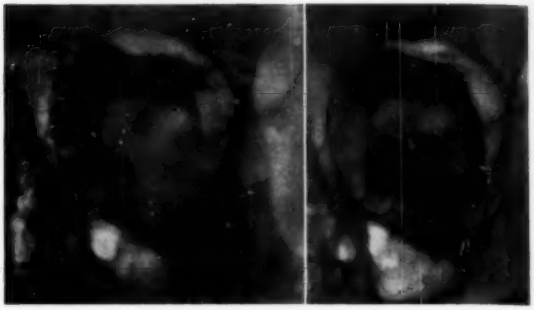


Fig. 8. Deep cystic hemoangioblastoma removed completely transfrontally. The neoplasm was shown more clearly by the contrast medium after 8 minutes.

In *deep neoplasms*, out of reach of palpation, the indications given by orbitography are better and it seems to us that the results obtained are very significant. The considerable difficulties met with when interpreting orbitography usually depend on the technique. In many cases the examination has been repeated more than once in order to formulate the grounds for an observation and to exclude false appearances. Provided that such precautions are taken, pre-operative radiologic diagnosis has always been subsequently confirmed.

Conclusions

Contrast media of the Umbradil (diodone) type of about 20 % do not injure the endo-orbital tissues and give good roentgenographic contrast. The media should be injected into the muscular conus.

In a material of 50 cases, 15 examinations were unsatisfactory owing to defective technique. The patient usually withstands the examination well; complications are rare and disappear without after-effects.

The fundamental indications for orbitography are the presence of tumours and pseudo-tumours.

SUMMARY

The technique of orbitography by means of water-soluble contrast media is described. The results of the examination in 50 cases are presented and discussed.

ZUSAMMENFASSUNG

Die Technik der Orbitographie mit wasserlöslichen Kontrastmitteln wird beschrieben. Die in 50 Fällen erzielten Untersuchungsergebnisse werden vorgelegt und diskutiert.

RÉSUMÉ

L'auteur décrit la technique de l'orbitographie avec des produits de contraste hydrosolubles. Il présente et étudie les résultats de cet examen dans 50 cas.

REFERENCES

Chinaglia, V. and Santelli, F.: Impiego di mezzi di contrasto nella diagnostica delle affezioni dell'orbita. Riv. Oto-neuro-oftal. 29 (1954), 24.

Cowie, J. W. and Groves, J. S.: Preliminary report on the use of contrast media in orbital radiography. Brit. J. Ophth. 29 (1955), 283.

Gifford, H.: Motor block of extraocular muscles by deep orbital injection. Arch. Ophth. 41 (1949), 5.

Katz, D. and Ledoux, A. C.: Measurement of antero-posterior diameter of eyeball in situ correlated with micrometer measurement following enucleation. Am. J. Ophth. 18 (1935), 914.

Manchester, P. T. and Bonmati, J.: Jodopyracet (Diodrast) injection for orbital tumors. Arch. Opth. 54 (1955), 591.

Manchester, P. T., Bonmati, J., Leigh, T. F. and Calhoun, F. P.: Experimental orbitography. Am. J. Roentgenol. 74 (1955), 508.

Mazzi, L.: Orbitografia posteriore con mezzo di contrasto liquido. Il Fracastoro 46 (1953), 153.

— Orientamenti nell'orbitografia con mezzi di contrasto liquido. Riv. oto-neuro-oftal. 30 (1955), 405.

Montresor, D.: Orbitografia con mezzi di contrasto. Atti Soc. Oft. Lomb. 2 (1952), 258.

— Ulteriore contributo all'indagine orbitografica con mezzi di contrasto iodici idrosolubili. Riv. oto-neuro-oftal. 29 (1954), 258.

Pettinati, S.: La localizzazione radiologica dei corpi estranei orbitari con l'ausilio dei mezzi di contrasto idrosolubili. Rass. ital. Ottal. 22 (1953), 587.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. GREGERS THOMSEN), AND EYE DEPARTMENT (DIRECTOR: PROF. H. EHLERS), UNIVERSITY HOSPITAL, COPENHAGEN, DENMARK

ORBITAL PNEUMOGRAPHY

by

Torstein I. Bertelsen and *Olaf Petersen.*

In the diagnosis of non-inflammatory, space-filling lesions in the orbit, roentgenography has hitherto been of limited value. The retrobulbar soft tissues are so surrounded by bones that superimposition occurs. Furthermore, tomography does not permit an exact evaluation of the individual soft-tissue components of the orbit. It is true that roentgenography can disclose destruction in the bony frame of the orbit and thus afford important data regarding the origin of the space-filling lesion, *e. g.* whether it is a lesion extending from the maxillary antra, ethmoid cells, frontal sinuses, or cranial fossa, into the orbit. But if the bony orbital structures are intact, the radiologic findings will far too often be "diffuse soft-tissue shadow in the orbit" which is equally unsatisfactory to the ophthalmologist and the roentgenologist.

It is not too much to say that improvement in the roentgenologic diagnosis in orbital lesions is overdue. The problem has indeed — though at long intervals — been discussed by various authors during the past 30 years. All these contributions have been concerned with injecting Tenon's capsule or the retrobulbar space with a contrast medium which can diffuse in the loose connective tissue and thus permit differentiation of the various soft-tissue structures in the film. In recent years the introduction of the tomographic technique opened up the way for a more exact diagnosis.

The first experiments in injecting contrast medium into the orbit were carried out in 1927 by STAUNIG & HERRENSCHWAND whose experimental objects were calf heads and live rabbits and their contrast medium was air, deposited in Tenon's capsule with the object of visualizing the posterior surface of the eyeball and the optic nerve. The result was fairly satisfactory, and subsequent authors (GASTEIGER & GRAUER 1929, SPACKMAN

Submitted for publication 24 January 1957.

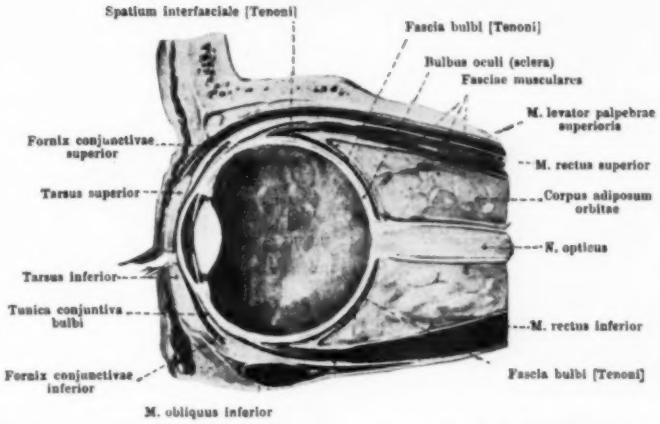


Fig. 1. Anatomy of the orbit. Tenon's capsule or Tenon's interfascial space is the loose connective tissue delimited anteriorly by the sclera and posteriorly by the fascia bulbi. The fascia bulbi is situated anteriorly between the bulbar part of the conjunctiva and the sclera, and fuses with the latter immediately behind the sclero-corneal junction. (After SPALTEHOLZ).

1932, SCHEIE & HODES 1946, FRIEDMAN 1947) used the method in human subjects, mainly in order to improve the possibilities of locating foreign bodies following double perforation of the eyeball. In more recent publications (LAST 1938, OFFRET et coll. 1954, COWIE & GROVES 1955, DUBILIER et coll. 1956, DE ABREU 1956), however, the main stress is laid on the applicability of this method in diagnosing intraorbital tumours.

Negative contrast media (air or oxygen) or positive contrast media (water soluble or oily substances) have been employed. The oily media — Lipiodol etc. — (SANDERA 1930, FERBEROW & MEDVEDEV 1935) do not have much to recommend them, partly because they are not distributed evenly in the connective tissue and partly because their absorption is slow so that they may give rise to chronic, reactive inflammatory changes. Aqueous media (COWIE & GROWES 1955) on the other hand, are absorbed so quickly — in the course of about 10 minutes — that they leave no time for an ordinary tomographic study. Air appears to have been preferred during recent years by most authors; it is not irritating, and its absorption is relatively slow, taking place within 24 to 48 hours.

The techniques of injection differ according to whether the contrast medium is to be introduced into Tenon's capsule or into the retrobulbar space (Fig. 1). If the clinical features indicate a juxta-bulbar tumor or perhaps a tumour originating from the globe proper, injection into

Tenon's capsule is indicated, whereas a suspected space-filling lesion far from the eye, perhaps in the orbital wall, calls for retrobulbar injection of the air.

Fig. 2. Emphysema of lower eyelid and bulbar conjunctiva, extending to the limbus corneae after insufflation of air into Tenon's capsule.

Injection of Tenon's capsule is generally performed by the following technique (advocated by FRIEDMAN 1947). After the conjunctiva has been anaesthetized with cocaine, the eyeball is held by a small pair of forceps in a position of internal and downward rotation. A curved needle is inserted by the transconjunctival route through the fascia bulbi in the upper temporal quadrant, just at the attachment of the lateral rectus muscle. The needle is then passed along the curvature of the eyeball towards its posterior pole. Having satisfied himself that the needle is not in a blood vessel, the operator then injects 5 to 6 ml of air; an ordinary dry-sterilized gas-tight 10 ml syringe is used. If the needle has been in the correct position, the injection causes an immediate increase in the exophthalmos of 2 to 3 mm and an increase in the intrabulbar pressure of 8 to 10 mm Hg. During the insufflation the patient has a sensation of pressure behind the eyeball, but the discomfort is immediately relieved when the injection is completed.

Injection of air into the retrobulbar space should preferably be done through the temporal part of the lower eyelid. A straight needle, 3 to 4 cm long, is inserted percutaneously in an upward, medial, and backward direction towards the posterior pole of the eyeball. The plunger of the syringe being withdrawn slightly to confirm that a blood vessel has not been entered, 15 to 20 ml of air are injected. As a rule, the first 15 ml are easy to inject after which a slight elastic resistance is encountered.

It is important that the needle and the syringe fit well and the latter must not be changed during the procedure as some of the air will then escape.

Part of the injected air may spread from the retrobulbar space through the orbital septum into the eyelids which often show quite considerable emphysema. Injection of Tenon's capsule is invariably accompanied by emphysema of the bulbar conjunctiva, which may at times extend as far as the corneal limbus (Fig. 2).

Ordinary views of the orbit in two planes seldom afford information of value, and tomography in two planes has to be carried out. In the antero-posterior projection, the sections should preferably be at right angles to the orbital axis, *i. e.* a line drawn from the middle of the optic foramen to the centre of a plane through the anterior limit of the orbit.

The sections should be at maximum intervals of 0.5 cm, from 2 to 7 cm in the a.p. plane and from 2.5 to 6.5 cm in the lateral plane.

Complications of this method are extremely rare — judging from the literature. In France DOLLFUS (1953) has reported a case of air embolism after retrobulbar insufflation of air. Injection of 5 ml was followed by left-sided convulsions with torsion of the head towards the right shoulder, vasoconstriction in the right half of the face, and unconsciousness. Ophthalmoscopy revealed air in the retinal vessels. All the signs subsided, however, within 20 minutes. Subsequent operation revealed that the exophthalmos in this case was caused by a cavernous haemangioma adhering to the optic nerve.

Subconjunctival haemorrhages and minor haemorrhages in the orbit are probably not uncommon, but they subside spontaneously without treatment. The risk of infection in the orbit appears to be slight.

Contra-indications to this examination are: 1) Infections in the orbit; 2) suspected injury of the eyeball. Owing to the increase in the intrabulbar pressure caused by the insufflation of air, loss of the vitreous body may occur.

Present series

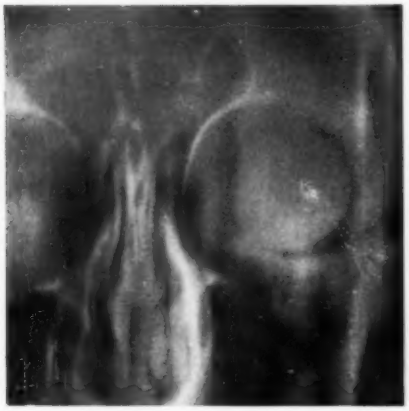
The method was adopted for testing about one year ago in our department. During this period we have examined a total of 8 patients with unilateral exophthalmos after all other types of examinations had failed to reveal the cause. So far, the insufflation has been performed by an ophthalmologist, but the technique is so simple that it can be mastered after some practice by any radiologist.

The effectivity of the method is illustrated by a few brief case reports.

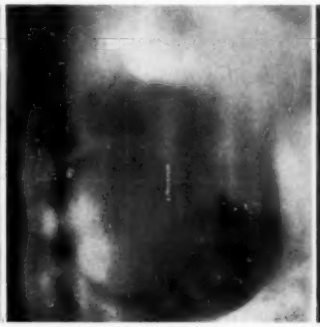
Figs. 3 to 4 show the distribution of the air in the orbit after insufflation of Tenon's capsule in a 46-year-old patient with unilateral exophthalmos. The antero-posterior as well as lateral tomograms sharply set out the contours of the eyeball. Some of the air has forced its way into the lower eyelid which shows marked emphysema, and a small portion of the air has become deposited in the retrobulbar space. In this case the examination ruled out a juxtabulbar tumour as the cause of exophthalmos.

In the following two cases, orbital pneumography gave more positive information of considerable diagnostic and therapeutic value.

Figs. 5 to 7 are from a case of a 49-year-old man who for the previous 2½ years had been exhibiting slowly progressing right-sided exophthalmos. Apart from mild diplopia on gazing at close objects, he did not have any symptoms at the outset. He had been admitted three times to an ophthalmologic and once to a neurosurgical department. In addition to a number of ophthalmologic examinations, he had had air encephalography and carotid angiography, all without avail. Roentgenography of the skull, nasal sinuses, and tomography of the orbit showed no abnormality. When the patient was first seen, his vision had been normal, but as it gradually deteriorated to 6/36, orbital pneumography was decided upon as the last diagnostic resort. Through the temporal part of the lower



Figs. 3—4. Air in Tenon's capsule. Outlines of eyeball are sharp in antero-posterior as well as lateral tomograms. No signs of space-filling lesions in anterior orbit. Considerable emphysema of lower eyelid.



Figs. 5—7. Air in Tenon's capsule as well as in retrobulbar space. Well-defined soft-tissue mass superiorly, posteriorly, and medially, just below the orbital roof. Lateral tomogram shows optic nerve to be displaced slightly downwards.

eyelid, 8 ml of air was injected into retrobulbar space. Both the antero-posterior and the lateral tomograms show a cushion-shaped soft-tissue mass situated superiorly, medially, and posteriorly in the orbit close to the orbital roof, but separated almost throughout from the latter by a narrow rim of air. This soft-tissue mass was well-defined and was pressing the optic nerve downwards. The operation which followed fully confirmed the roentgen findings. At the site stated there was a walnut-sized, bluish-red tumour, delimited from the surrounding tissue by a distinct capsule. Microscopic examination revealed a mixed tumour, presumably originating from an aberrant primordium of the lacrimal gland.

Fig. 8. Air in retrobulbar space with only a little in Tenon's capsule. Ill-defined filling defect, merging with eyeball, in angle between optic nerve and inferior part of eyeball.

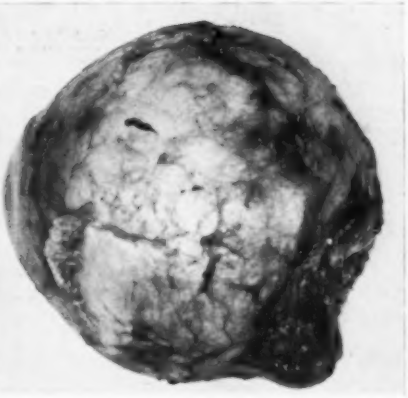


Fig. 9. Same case. The enucleated eye with invasion of sclera at site where pneumography showed the ill-defined filling defect. Microscopic examination: Malignant choroid melanoma.

Figs. 8 to 9 show orbital pneumography in a 72-year-old man who had gradually, in the course of 4 months, become totally blind in one eye. He has 3 mm exophthalmos and severe ciliary injection. Ophthalmologic study had indicated melanosarcoma. Orbital pneumography was done, because the ophthalmologists wanted to know whether the tumour had invaded the sclera posteriorly. Antero-posterior tomography gave no definite information, but in the lateral views a soft-tissue shadow merging with the globe was noted in the angle between the lower limit of the optic nerve and the posterior bulbar wall. In this case too, the operation confirmed the roentgen findings. Fig. 9 shows the eye after removal. The pea-sized invasion lay immediately below and nasal to the optic nerve. Microscopic examination revealed a malignant choroid melanoma.

Conclusions

Our experience with orbital pneumography is limited although promising. The technique is relatively simple, and when the examination is correctly performed there is little risk of serious complications. The method may afford valuable data regarding the size, limits, and exact localization of a tumour, factors of the utmost importance in choosing the operative line of approach.

SUMMARY

The technique of examining the orbit roentgenologically after insufflation of air into Tenon's capsule or into the retrobulbar space is described. The effectivity of the method is illustrated by case histories.

ZUSAMMENFASSUNG

Die Technik der röntgenologischen Untersuchung der Orbita nach Insufflation von Luft in die Capsula Tenoni oder in dem retrobulbären Raum wird beschrieben. Die Effektivität der Methode wird mit Krankengeschichten illustriert.

RÉSUMÉ

Description de la technique d'examen radiologique de l'orbite après insufflation d'air dans la capsule de Tenon ou dans l'espace rétrobulbaire. L'utilité de cette méthode est démontrée par des exemples.

LITERATURE

Cowie, J. W. & Groves: J. S.: Preliminary report on the use of contrast media in orbital radiography. Brit. J. Ophth. 39 (1955), 283.

De Abreu, M.: Orbital emphysema. Am. J. Ophth. 35 (1952), 1269.

Dollfus: cit. by Offret et coll.

Dubilier, W., von Gal, H., Freemond, A. & Evans, J. A.: Orbital pneumotomography. Radiology 66 (1956), 387.

Farberow, N. I. & Medvedev, N. J.: Sur la localisation des corps étrangers de l'œil a l'aide de substances contrastantes introduites dans l'espace de Tenon. J. de radiol. et d'électrol. 19 (1935), 97.

Friedman, B.: Use of air injections into Tenon's capsule for localization of orbital foreign bodies. Arch. Ophth. 38 (1947), 660.

Gasteiger, H. & Grauer, S.: Zur Diagnose der Doppelperforation des Augapfels mit Hilfe von Lufteinblasung in den Tenon'schen Raum. Fortschr. Röntgenstr. 40 (1929), 272.

Hughes, W. L. & Cole, J. G.: Technical use of air in ophthalmology. Arch. Ophth. 35 (1946), 525.

Last, M. A.: Contrast mediums in orbital roentgenography. Arch. Ophth. 19 (1938), 1031.

Offret, G., Gilles, E. & Blanchot, F.: De l'intérêt des tomographies orbitaires avec injection d'air en ophthalmologie. Arch. d'ophth. 14 (1954), 259, 352.

Sandera, R.: Pneumotenon. Über eine neue kombinierte Kontrastdarstellung des Spatium interfasciale Tenoni und der hinteren Sklera. Röntgenpraxis 2 (1930), 175.

Scheie, H. G. & Hodes, P. J.: Injection of oxygen into Tenon's capsule. Arch. Ophth. 35 (1946), 13.

Spackmann, E. W.: X-ray diagnosis of double perforation of the eyeball after injection of air into the space of Tenon. Am. J. Ophth. 15 (1932), 1007.

Staunig, K. & v. Herrenschwand, F.: Experimentelle Versuche der Röntgendifferenzierung des Augapfels. Fortschr. Röntgenstr. 36 (1927), 372.

FROM ROENTGENDIAGNOSTIC DEPARTMENT III (DIRECTOR: I. WICKBOM),
SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

ARTERIAL 'SPASM' IN PERIPHERAL ARTERIOGRAPHY USING THE CATHETER METHOD

by

Ingmar Wickbom and *Osborne Bartley*

The technique described by Dos Santos in 1931 for examination of the arteries of the extremities, the injection of the contrast medium being made through a needle placed in one of the large arteries, is well suited for studying vessels near the site of puncture. For the examination of more peripheral branches this method requires, however, that a comparatively large amount of contrast medium in high concentration be employed, since the medium is rapidly diluted during its passage in the blood stream.

Leaving Thorotrast out of consideration since this substance may nowadays, due to the hazards of radiation injury, be regarded too risky to employ, the fact still remains that the other contrast media that are available cause pain reactions which become greater the higher concentration of the contract medium is. It may therefore sometimes be necessary to perform the examination under general anesthesia. If very high concentrations are used permanent damage of such a serious nature may be caused that, according to reports in the literature, amputation may be necessary.

By catheterization of the vessel the injection can be made closer to the vascular region concerned. Thus, despite the use of a comparatively

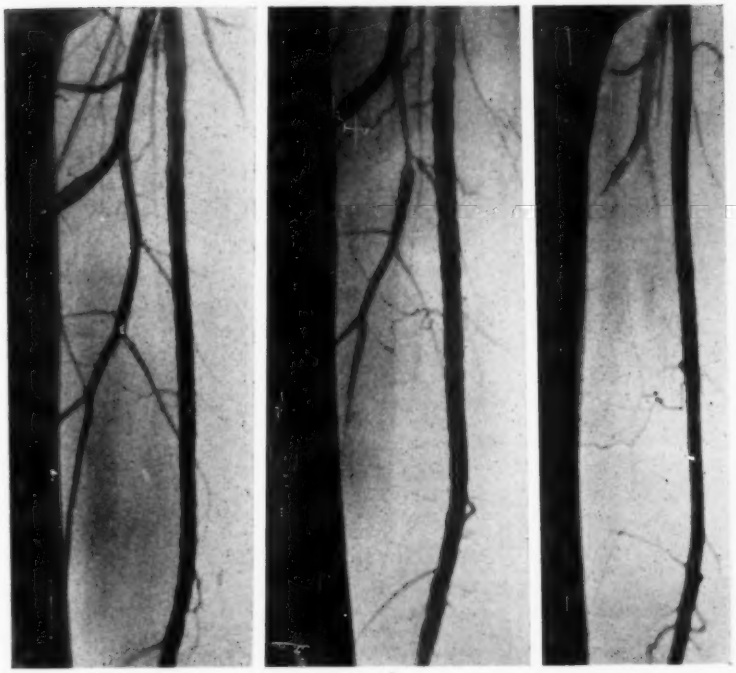
Submitted for publication 17 April 1957.

small amount of contrast medium of lower concentration, it is possible in this manner to obtain a more satisfactory contrast filling of the peripheral branches. Another advantage provided by the catheter method is that the examination can be better timed so that the exposure of films may be concentrated to the period at which the contrast filling of the vessels is optimal within the region to be studied. This is important, especially in examinations with rapid serial film exposures, in order to reduce as much as possible the radiation dose and the consumption of film.

Yet, even when the catheter method is employed and even in the absence of an organic obstruction of the vessel, it may happen that the filling of the peripheral branches is incomplete. Having made the observation that in such cases the circulation, at least in the peripheral parts of the vessels, is conspicuously slow we suspected that this might be due to vascular contraction. We have as a matter of fact also been able to demonstrate local changes in the vessels which we have interpreted as being caused by vascular contraction, for reasons to be discussed later. In the following we shall refer to this condition as spasm.

In large vessels we observed a change of this type for the first time in a patient with Raynaud's disease and we even thought that the change might be specific for a disease of this kind. In a discussion with Åke Lindbom at Karolinska Sjukhuset he mentioned that local vascular contractions may occur normally in connection with arteriographies of the extremities. With a view to evaluate the frequency of such changes in our own material we have undertaken a survey of the material of angiographies of the extremities carried out in Roentgen Department III of Sahlgrenska Sjukhuset in the years 1955—1956.

During these years the technique employed was on the whole uniform and corresponded to the following procedure. After percutaneous puncture, a plastic catheter is inserted in accordance with the method described by Seldinger: a flexible metal guide is introduced by way of the puncture needle; after the needle is pulled out, the catheter is mounted around the metal guide and the latter is thereafter withdrawn. For investigations of the arteries of the leg, the femoral artery is punctured at the level of the inguinal ligament and the catheter is if possible so directed that the tip lies in the proximal part of the popliteal artery. After examination of the lower leg and foot, the catheter is retracted so that the tip lies only a few centimeters distal to the puncture; the vessels of the upper leg are then examined. If the catheter, as may happen, slips down into the deep femoral artery, a further attempt is made to place the tip in the femoral artery. Should this also fail, the injection is performed with the catheter inserted only a few centimeters into the vessel with the tip resting proxim-



a b c

Fig. 1. Male, aged 32. Buerger's disease. a) Catheter in femoral artery, where small circular constrictions are seen. b) Repeat examination 3 weeks later. Catheter in femoral artery, after having first been introduced in deep femoral artery. Spasm in femoral artery is now more marked with deep circular constrictions. One branch from the deep femoral artery which at the first examination had normal appearance is now very narrow. c) After administration of Priscol through the catheter, spasm in femoral artery has almost completely disappeared; spasm in deep femoral artery on the other hand remains almost the same.

al to the origin of the deep femoral artery. In such instances, however, the filling of the peripheral branches has as a rule been less complete.

For examination of the arm, the brachial artery is punctured, generally at about the middle of the upper arm or somewhat more proximally. The catheter is introduced in such a way as to permit the tip to be placed in the distal part of the brachial artery. The metal guide, on the other hand, has probably as a rule been introduced as far as the level of the elbow.

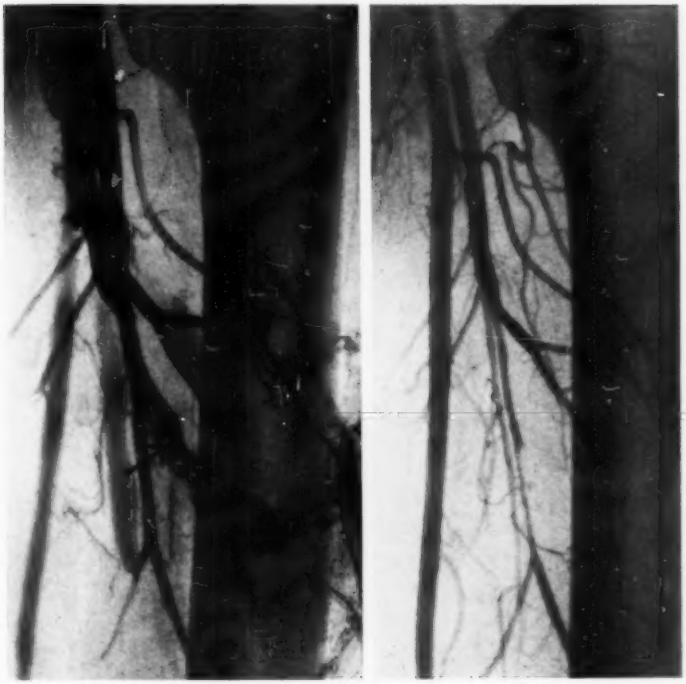
Fig. 2 a b Fig. 3.

Fig. 2. Female, aged 24, with signs of acrocyanosis. a) Brachial artery narrow in its proximal part. Small circular constrictions are also seen. Retrograde filling of the vessel proximal to the catheter. b) After administration of Priscol brachial artery is of normal width. Circular constrictions have disappeared and no retrograde filling proximal to the catheter.

Fig. 3. Female, aged 48. Raynaud's disease. Proximal part of brachial artery much more narrow than distal part. Vessel also filled in retrograde direction. Small circular constrictions.

In practically all the cases the contrast medium has been Umbradil 35 %, injected in doses of 10 ml for the leg and 5 to 10 ml for the arm, for each series of films. In connection with each injection about 6 films have been exposed, with intervals of 1 to 2 sec. In tumour cases, however, a greater number of films were taken and the rate of exposure was higher.

The patients have described a sensation of burning pain in connection with the injection but this has only in exceptional cases been severe



a b

Fig. 4. Male, aged 48. Symptoms of intermittent claudication. a) Catheter in a small branch of deep femoral artery (→). Contrast medium passed rapidly over to the veins. b) Catheter now in femoral artery. That branch of the deep femoral in which the catheter was first introduced is not filled at all. Another branch is narrow.

enough to require general anesthesia. Recently, we have occasionally used Hypaque 45 % and this contrast medium appears to cause less discomfort to the patient.

Our analysis is based on a material of 108 angiographies of the extremities. In 6 cases films were taken with the catheter first lying in the deep femoral artery and thereafter in the femoral artery. These cases are represented with two examinations each in the present report. On the other hand, such cases in which the site of puncture and the catheter were not visible in the films have been excluded. For the same reason the investigations in which the catheter had been introduced in a central direction for the examination of the pelvic arteries and the subclavian artery have been excluded.

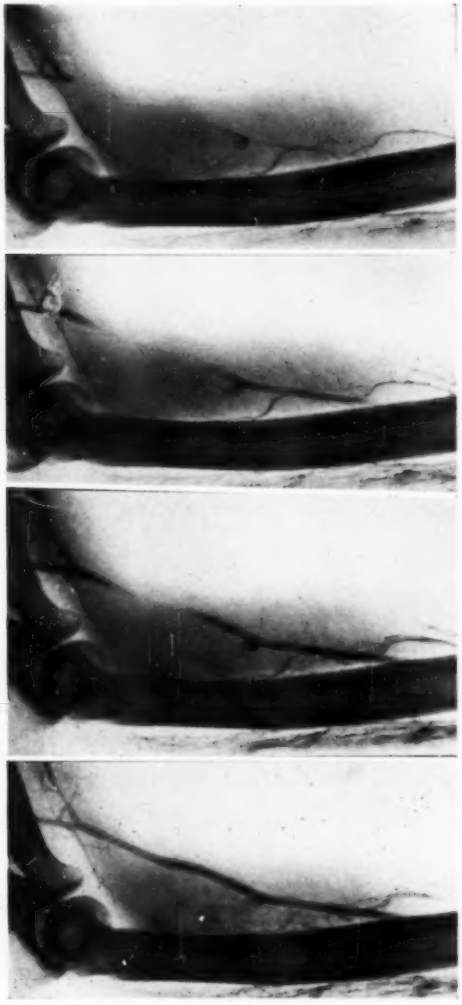


Fig. 5. Female, aged 38. Raynaud's disease. All films from the same series. Between a) and b) 1 sec, between b), c), and d) 2 sec interval. Brachial artery seems to be partly filled via collaterals from a small artery in which tip of catheter apparently lies. The brachial artery is gradually filled, partly in retrograde direction from these collaterals. At d) a spasm also in the radial artery.

Results

Local spasm was demonstrated in 42 of the 108 angiographies, which corresponds to 39 % of the whole material. In Figs. 1 to 6 spasm of various appearances is illustrated. Small circular constrictions are sometimes present, at others there is an even narrowing of the vessel in a circumscribed area; in all these cases there is often a retrograde filling of the vessel proximal to the catheter. The vessel occasionally may appear to be temporarily occluded.

With a view to a detailed analysis of the causes of the changes observed, the material has been grouped according to certain factors which could be expected to be of importance for the development of spasm, viz. a) age, b) sex, c) vascular region affected, and d) the type of disease for which the patient was examined. The results with respect to factors (a), (b), and (c) are assembled in Table 1.

The indications for arteriography have in most of the cases been circulatory disturbances, but the examination was in some cases undertaken for other conditions and then usually for a suspected tumour. As regards the indications for carrying out the angiographic examination the material has been classified in three groups with reference to the type of disease.

Table 1

Frequency of spasm correlated to age, sex and vessel examined

		POS. + NEG.		POS.		NEG.	
		number	average age	number (%)	average age	number (%)	average age
Total case material	♂	85	46	29 (34)	38	56 (66)	51
	♀	23	44	13 (57)	37	10 (43)	53
	♂ + ♀	108	46	42 (39)	38	66 (61)	51
Femoral artery	♂	53	47	10 (19)	35	43 (81)	49
	♀	11	48	2 (18)	22	9 (82)	54
	♂ + ♀	64	47	12 (19)	33	52 (81)	50
Deep femoral artery	♂	20	45	13 (65)	37	7 (35)	60
	♀	5	39	4 (80)	37	1 (20)	47
	♂ + ♀	25	44	17 (68)	37	8 (32)	58
Brachial artery	♂	12	47	6 (50)	45	6 (50)	49
	♀	7	41	7 (100)	41	0	
	♂ + ♀	19	45	13 (69)	43	6 (31)	49

A. Circulatory disturbances with organic vascular changes (arteriosclerosis, Buerger's disease).

B. Circulatory disturbances without evidence of organic changes (Raynaud's, and similar diseases).

C. Cases without signs of circulatory disturbances (mainly tumour cases, and cases of suspected tumour).

There was uncertainty in 5 cases as to the group in which to place them, and these were therefore excluded from this analysis.

The frequency of spasm in relation to age and sex distribution may be seen from Table 2.

From a study of Tables 1 and 2, and of Diagram 1 the following observations may be made.

1) Irrespective of the vascular region examined, the frequency of spasm in both sexes is on the average inversely proportional to the age distribution. The lower frequency of spasm with increasing age is probably due to reduced contractibility as a result of changes in the vascular walls due to age.

Table 2

Frequency of spasm correlated to the type of disease for which the patient was examined

A = circulatory disturbances with organic vascular changes.
B = circulatory disturbances without evidence of organic vascular changes.
C = cases without signs of circulatory disturbances.

		POS. + NEG.		POS.		NEG.	
		number	average age	number (%)	average age	number (%)	average age
A.	♂	63	47	20 (32)	37	43 (68)	51
	♀	5	58	0	—	5 (100)	58
	♂ + ♀	68	48	20 (29)	37	48 (71)	53
B.	♂	5	54	3 (60)	55	2 (40)	53
	♀	7	39	6 (85)	39	1 (15)	41
	♂ + ♀	12	45	9 (75)	44	3 (25)	49
C.	♂	13	39	5 (38)	28	8 (62)	46
	♀	10	38	6 (60)	31	4 (40)	49
	♂ + ♀	23	39	11 (48)	30	12 (52)	47

2) The spasm frequency is in our material higher for women than men, although for both sexes the mean age distribution is approximately the same.

3) The spasm frequency is lower in the femoral artery which is a large vessel as compared to the two other vessels concerned. No essential difference in age or sex distribution in the material exists that could explain this fact. That there is a difference in spasm frequency between different parts of the vessel is natural, since the mechanical influence of the catheter and metal guide, as well as the initial pressure increase in connection with the injection, must be greater the narrower the vessel. It is well known, *e. g.* in the surgery of fractures (LIPSCOMB and BURLESON 1955) that the mechanical pressure exerted on a vessel may cause long persisting spasm.

In our material, as a matter of fact, spasm occurred most frequently in those parts of the vessels in which the catheter and metal guide had been inserted. In a few cases, however, spasm was observed in vessels where neither catheter nor guide had been introduced (Fig. 6). It is known that water soluble contrast media may affect the walls of the vessels (FONTAINE 1937). With respect to the vessels of the brain, the dose and

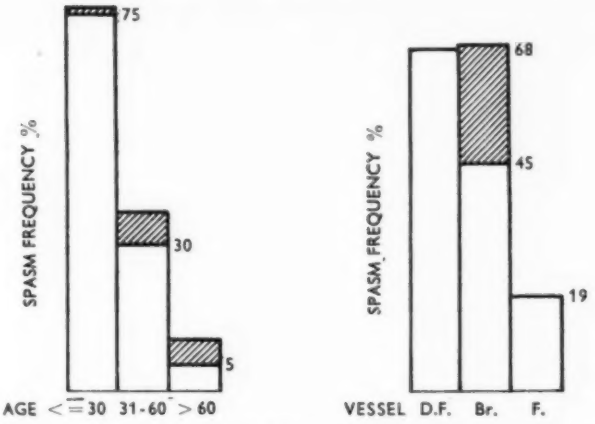


Diagram 1. Frequency of spasm correlated to the age of patient and the vessel into which the catheter is introduced. If the cases with Raynaud's disease are excluded (striped area) the spasm frequency is inversely proportional to age of patient and to width of vessel examined.

D. F. = Deep femoral artery; B. = Brachial artery; F. = Femoral artery.

concentration of the contrast medium are of vital importance (Broman and Olsson 1948, 1949). The extent to which the type, amount, and concentration of the contrast medium employed in our material may have exerted influence of this kind cannot be assessed, since the technique was not varied. In the future, it is our intention, however, to undertake comparative tests, primarily with Hypaque.

The spasm frequency is highest in group B, and in C somewhat higher than in A. The low frequency in A cannot be due to sub-representation of narrow vessels in the investigations, since almost all the angiographies of the deep femoral artery lie in this group. With respect to the other factors considered, the female sex is somewhat in a minority, and the mean age is represented by a higher figure than in the rest of the material; nevertheless, the essential cause of the low spasm frequency in group A should probably be sought in the reduced contractibility, due to the organic vascular changes which were demonstrated.

As far as the ability to contract is concerned, group C may be considered to represent a normal material.

The high frequency of spasm in group B suggests that the development of spasm may have been influenced by the type of disease for which the patient was examined. In a closer analysis of this group it became evident that the high frequency must be due entirely to the fact that 8 of these examinations were carried out in patients who clinically had been diag-

a b

Fig. 6. Male, aged 60. Raynaud's disease. Spasm in radial artery although neither catheter nor metal guide was introduced that far. b) After Priscol: Spasm has disappeared almost completely.

nosed as cases of Raynaud's disease. In all these 8 cases, spasm occurred. The respective examinations were performed with puncture of the brachial artery in five women and two men (bilaterally in one of these latter). The mean age was 47 years, which is a little high as compared with the rest of the material. From the 100 % frequency of spasm, despite the higher figure represented by the mean age (47 years as against 39 years in the other positive angiographies performed in the brachial artery), it is evident that this disease must be associated with some special tendency to spasm. It is also in this group that the changes demonstrated were most prominent.

Since Raynaud's disease, as regards its liability to produce spasm, is exceptional, we have in addition evaluated the rest of the material by itself, having excluded the above-mentioned 8 cases. This resulted in the female sex becoming less predominant, and the figure representing the spasm frequency in investigations of the brachial artery falling between the values derived for the femoral artery and the deep femoral artery respectively. The tendency to spasm development then becomes inversely proportional to the width of the vessel (Diagram 1).

That the changes which we have called spasm are of a functional nature is evident from the fact that they have not been constant. In a few cases they displayed a different appearance from one film to another in

Fig. 7.

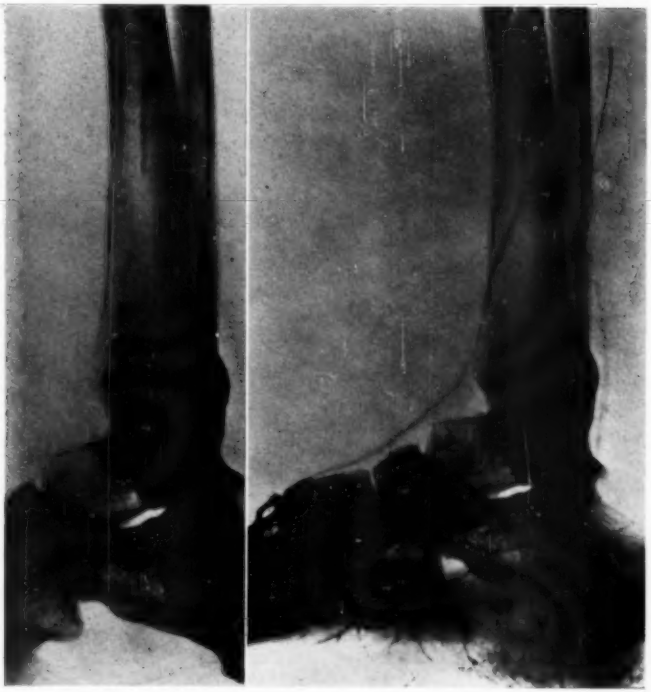
Fig. 8.

Fig. 7. Female, aged 52. 'Normal' case. Marked spasm in radial artery which is narrow, with circular constrictions.

Fig. 8. Male, aged 27. Marked constrictions of circumflex fibular and of anterior tibial artery, of similar appearances as those caused by spasm, but in this case due to Buerger's disease. (Cf. fig. 7.)

the same series, and in some other cases the changes appeared in one particular film sequence while in a subsequent series they were either less marked or had disappeared completely. In the majority of cases, however, the changes were consistent during the exposure of several film sequences, and it was then difficult to judge whether they were functional or due to organic anomalies (Figs. 7 and 8). Peripheral to the changes observed the circulation has been slow and the filling of the vascular branches incomplete.

It seemed natural as a consequence of these observations to make an attempt to solve the diagnostic difficulties produced by spasm by the administration of a vasodilator. In September 1955, after discussing the



a b

Fig. 9. Male aged 22. Diabetes. No clinical sign of circulation disturbances. a) Only poor and incomplete filling of the vessels. (This was the most complete filling obtained before administration of Priscol.) b) After Priscol: Complete filling of the vessels of the foot, film taken a few seconds after termination of injection.

matter with TORSTEN LINDQVIST of our medical department, we started using Priscol, as the patient in whom he had earlier tried this pharmacon was found to respond well to it.

Priscol (tolazoline) is a moderately effective adrenergic blocking agent. It causes vasodilatation by direct action on blood vessels. This effect is almost equal in normal and in sympathectomised vascular beds. It also produces a fall in blood pressure accompanied by tachycardia. It should be used with caution in patients with peptic ulcer and coronary artery disease.

An intra-arterial injection of 2 ml (50 mg) of this medium is given through the catheter. We try to perform the subsequent contrast medium injection at the moment when the effects of the Priscol are optimal, which is manifested by local blushing and temperature increase and which as a rule occurs about 5 minutes after its injection. No

pain reactions or other non-desirable effects of this preparation have been observed in any one of the cases in which it was applied.

Various vasodilating compounds exist, some of which produce a stronger effect than Priscol, as for instance acetylcholine. However, before testing other types we have first wanted to gain some experience from the use of Priscol.

In 2 cases (both with Raynaud's disease) where Priscol had little effect, we made an intravenous injection of 1 to 2 ml of Pendiomid, which is a ganglion-occluding medium, and the effects were definetely apparent. LINDBOM (1951) has recommended heating of the extremity in order to obtain a more complete contrast filling of the vessels. The administration of a drug is much more simple, however, and the effects appear earlier. In the cases where in addition we tried heating we have found that the effects of a drug were superior.

Due to the fact that Priscol has been found to influence the peripheral blood circulation in the presence of spasm, we have adopted it also in cases where the peripheral contrast filling was poor, even if we could not directly demonstrate any spasm.

Priscol has been used in 27 investigations. In 24 cases, the peripheral contrast filling became more satisfactory and the circulation time was reduced up to 20 seconds (Fig. 9). The passage to the veins became more rapid and the contrast filling of the veins more concentrated. Before the Priscol injection, the arteries of the hands and feet could not be demonstrated in 7 cases.

In 2 cases we failed to obtain any significant improvement in the filling of the peripheral branches. In both these there were considerable arterio-sclerotic changes, in one case with occlusion and in the other in the form of extensive calcifications of the media. It is probable that in these instances the incomplete filling was not a result of functional disturbances but due to organic changes. In one case with tumour of the upper leg no attempt was made to investigate the peripheral branches. This patient was given a Priscol injection for spasm in the femoral artery.

To investigate how the spasm was influenced by Priscol, the region of spasm was in 7 cases studied after injection of this preparation. In 5, the spasm either disappeared or diminished considerably. In one case the difference between the conditions before and after the injection of Priscol was less prominent but the effect was nevertheless quite obvious. After the intravenous injection of 100 mg Pendiomid the spasm disappeared almost completely.

In one case with a spasm of somewhat different character than the rest (Fig. 5), the condition was not affected by Priscol, but the rate of blood circulation somewhat increased.

It must obviously be a matter for discussion whether the diminuation of the spasm observed after the administration of Priscol was in reality due to the preparation, as in one case the condition of spasm disappeared spontaneously between two film series. But we have also in several cases observed that the spasm persisted unchanged in several film sequences, and that it disappeared only after giving Priscol. In these cases at any rate it seems likely that the diminution of the spasm was produced by the vasodilator.

Conclusions

Local contractions, which in this paper are called spasm, may occur during angiographies performed with a catheter. They generally arise in those parts of the vessels where the leader or the catheter have been inserted, but they have also been observed in more peripheral regions.

The frequency of spasm is on the whole inversely proportional to the age of the patient and to the width of the vessels in the region examined. This implies that on the average the mean age should be high for those who do not develop spasm when the catheter lies in the deep femoral artery, while it should be low for those who develop spasm in the femoral artery. Our material provides confirmation of these assumptions, the respective figures being 58 and 33 years. Spasm in our material occurred somewhat more frequently in women than in men.

A specific tendency towards development of spasm is apparent in patients with clinical signs of Raynaud's disease.

As a consequence of the spasm and due to the resultant incomplete filling it may be impossible to visualise peripheral vascular regions. The changes that arise may vary and it is sometimes hard to judge by their appearance whether they are of organic or functional origin. If a vascular contraction is due to spasm it is generally possible to reduce the spasm or make it disappear by the administration of a vasodilating agent (such as Priscol). Simultaneously the rate of circulation is increased and a more satisfactory filling of the peripheral vessels is obtained. Even when there is no direct evidence of spasm, filling of the peripheral branches as a rule becomes more complete after the injection of Priscol.

In investigations of the extremities according to the technique adopted we have not observed that the spasm caused complications of any significance.

It is probable, however, in examinations of organs which are sensitive to ischemic conditions of short duration — *e. g.* the brain — that spasm of this type may lead to serious complications. In 2 out of 20 cases, in which we used the same catheter method for an examination of the carotid artery, we encountered complications in connection with the angiographic examination; in at least one of these cases the complications were due to the condition of spasm.

SUMMARY

An analysis of 108 angiographies of the extremities performed with a catheter showed that local spasm occurred in 39 %. The frequency of spasm was inversely proportional to the age of the patient and to the width of the vessels examined. It was found to occur frequently in Raynaud's disease and more commonly in women than in men. The value of vasodilators both for reducing or eliminating spasm and filling the peripheral vessels is stressed.

ZUSAMMENFASSUNG

Die Analyse von 108 mit einem Katheter ausgeführten Angiographien der Extremitäten zeigte, dass lokale Spasmen in 39 % auftraten. Die Frequenz des Spasmus war umgekehrt proportional zu dem Alter des Patienten und zu der Weite der untersuchten Blutgefässe. Man fand, dass Spasmen häufiger bei der Raynaud'schen Krankheit auftraten und dass sie bei Frauen öfter als bei Männern vorkamen. Der Wert von Vasodilatatoren für die Reduzierung oder Eliminierung des Spasmus sowie für die Ausfüllung der peripheren Gefässe wird betont.

RÉSUMÉ

L'étude de 108 angiographies des extrémités par cathéterisme a montré qu'il se produit un spasme local dans 39 % des cas. La fréquence du spasme a été inversement proportionelle à l'age du malade et au calibre des vaisseaux examinés. Il s'est produit fréquemment dans la maladie de Raynaud, et plus souvent chez les femmes que chez les hommes. Les auteurs insistent sur l'intéret des vasodilatateurs pour réduire ou supprimer le spasme et pour remplir les vaisseaux périphériques.

REFERENCES

Broman, T. and Olsson, O.: The tolerance of cerebral blood-vessels to contrast media of the diodrast group. Acta radiol. 30 (1948), 326.

— Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral vessels. Acta radiol. 31 (1949), 321.

Console, A. D.: Segmental arterial spasm associated with supracondylar fracture of the elbow. Report of a case. Surg. Clin. N. Amer. 28 (1948), 467.

Dos Santos, R., Lamas, A. C. et Caldas, J. P.: Arteriographie des membres et de l'aorte abdominale. Masson, Paris 1931.

Fontaine, R.: L'artériographie des membres. Sa technique, ses résultats dans les affections vasculaires. J. int. Chir. 2 (1937), 559.

Goodman, L. and Gilman, A. The pharmacological basis of therapeutics. Mc Millan, New York 1955.

Gumrich, H., Dortenman, S. u. Kübler, E.: Zur Diagnostik örtlich bedingter Arterienveränderungen. Fortschr. Röntgenstr. 86 (1957), 162.

Kalowski, J.: Segmental arterial spasm of the brachial artery. Surgery 38 (1955), 1087.

Lindbom, Å.: Arteriosclerosis and arterial thrombosis in the lower limb. A roentgenologic study. Acta radiol. Suppl. 80 (1950).

— Angiographie. *In*: Schinz, Baensch, Friedl, Uehlinger: Lehrbuch der Röntgendiagnostik, 5. Aufl. S. 1801. Georg Thieme, Stuttgart 1951.

— Personal communication.

LINDQVIST, T.: Personal communication.

LIPSCOMB, P. R. and BURLESON, R. J.: Vascular and neural complications in supracondylar fractures of the humerus in children. J. Bone Joint Surg. 37 A (1955), 487.

SELDINGER, S. I.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 368.

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT D (DIRECTOR: DOCENT ÅKE LINDBOM), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

ARTERIAL SPASM CAUSED BY PUNCTURE AND CATHETERIZATION

An arteriographic study of patients not suffering from arterial disease

by

Åke Lindbom

The increasing use of intraarterial catheterization in connection with arteriography has revealed that spasm of medium-sized arteries, *e. g.* the brachial artery, is common during this procedure.

During the 1914—18 War spasm was seen in the main arteries of the extremities, generally in connection with perforating gunshot wounds in the proximity of the artery. The first to describe this phenomenon was KROH, and a review of the experiences from this war was published by KÜTTNER and BARUCH (1920). At operation the undamaged arteries were found to be wholly contracted so that no blood could pass through. MONTGOMERY and IRELAND described a similar spasm in connection with supracondylar fractures in children. A review of traumatic arterial spasm was made in 1944 by COHEN. KINMONTH et coll. (1949) and KINMONTH (1952) performed experiments in rabbits and cats and came to the conclusion that a local segmental spasm could be produced in the large arteries by mechanical trauma, irrespective of the presence of the adventitia and possible nerve supply. They furthermore stated that electric stimulation of the nerve supply failed to reveal evidence of nerve motor control of the large arteries. The working hypothesis was accepted that traumatic spasm is due to mechanical stimulation of the vessel wall resulting in a sustained contraction of smooth muscle, in the maintainance of which nervous factors do not play a demonstrable part.

Submitted for publication 25 January 1957.

a b

Fig. 1. Spasm of brachial artery demonstrated by arteriography. Girl aged 16. a) Contrast injection through needle introduced in a proximal direction into brachial artery. Contraction of artery at entrance of needle and at tip. Lumen narrowed between these points. b) Injection through catheter introduced with Seldinger's method with artery wholly contracted around catheter for approximately 2.5 cm. (High origin of the ulnar artery visible only in b) because of the more proximal injection.)

MUSTARD and SIMMONS observed in dogs that arterial spasm could be produced by stretching of the arterial system. LERICHE treated this subject in several publications. Spasm of the femoral artery was seen at arteriography in one case by GESENIUS. SCHRADER believed arterial spasm to be rare. Spasm in the brachial artery in connection with an intravenous infusion was reported by SUTTON. LÄWEN in 1934 described spasm of the femoral artery in 2 cases of venous thrombosis; this finding, however, seems to be unique in the literature.

Method and material. The brachial artery was punctured percutaneously at the elbow using a 0.8 or 1.0 mm bore needle. A polyethylene catheter with an outer diameter of 1.27 or 1.57 mm, according to the bore, was then introduced using the *Seldinger* method. In this procedure a flexible metal or nylon guide is introduced into the vessel through the needle; a catheter is then threaded on to the guide and pushed into the vessel; the guide is then withdrawn.

Arteriography was performed by injection both through the needle before the cathe-

a b

Fig. 2. Angiography of brachial artery showing spasm caused by puncture and catheterization. Woman, aged 48. a) Injection through needle. Contractions at entrance and at tip of needle. (→). b) Injection through catheter a few minutes after a. 'Total' contraction 3 cm in length (←). proximally short contractions (↔). Blood supply to forearm through collaterals.

ter was introduced and through the catheter. In several cases the arteriographic examination through the catheter was repeated at different intervals; in some cases arteriography was carried out with different positions of the catheter. The needle was in most cases introduced in the proximal but in some cases in the distal direction.

Twenty patients referred to the roentgen department for urography were examined. The same technique was used in each case. No evidence of arterial disease in the arm to be examined was elicited from the history or was found on inspection or palpation.

In 10 patients suffering from a tumor of the arm, arteriography was performed with a similar but somewhat varied technique. The puncture was in some cases made into the subclavian or the proximal part of the brachial artery.

Arteriographic experiments and observations were furthermore made in the lower extremity in 20 cases, mostly of tumors.

Arterial spasm. The typical appearances of an artery with a puncture needle introduced are demonstrated in Figs. 1 and 2. A contraction,

Fig. 3. Decrease of spasm of brachial artery caused by catheterization. Woman aged 53. a) Marked contraction. Blood supply to forearm mainly through collaterals. Brachial artery pushed forward by haematoma behind the vessel. b) After 30 min haematoma decreased. Spasm considerably diminished both in region of haematoma and proximally. Blood flow to forearm through brachial artery.

which was usually marked, was seen at the entrance point of the needle into the artery; in many cases the artery was wholly contracted around the needle at this site. Another contraction was visualized in the region of the tip of the needle; the artery between these two points was usually contracted although in most cases not totally. There was never any narrowing of the lumen proximal or distal to the needle.

When a catheter had been introduced into the vessel, the contraction was in all cases more marked (Figs. 1 and 2). In about half the cases the artery was contracted around the catheter so that no lumen was left between the arterial wall and the catheter. When the artery was wholly contracted around the catheter the blood to the lower arm and the hand passed through collaterals around the elbow (Fig. 2 b). The blood supply through these was sufficient, the arm being at rest, and the contraction

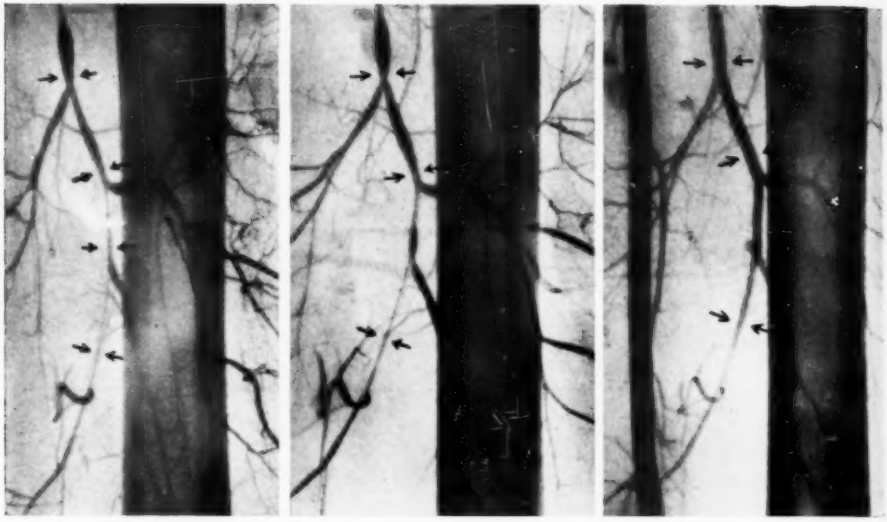
of the brachial artery was not appreciated by the patient. Naturally the radial pulse could not be palpated in this state.

In several cases the contraction of the artery had decreased when arteriography was repeated after an interval of about half an hour, although the catheter remained in the vessel throughout (Fig. 3). In some of the cases with a total contraction around the catheter the radial pulse returned at the very instant the catheter was withdrawn, and in one case only a little while after this had been done. In one case the radial pulse was not palpable one hour after the withdrawal of the catheter. The patient experienced no discomfort but the hand was felt to be colder than on the other side.

In about half of the cases the contraction of the artery around the catheter was not total and a lumen was preserved between the inner wall of the vessel and the catheter (Fig. 4). The artery was, however, narrowed in all cases in which a catheter was present in the lumen. In some cases the lumen was very irregular with many short circular contractions and in others more uniformly narrowed. In several cases the contractions were seen to have exactly the same appearance in several films exposed with either an interval of a few seconds or of 10 to 15 min. In some instances contractions were seen to remain in an artery into which a metal or nylon guide had been introduced during the procedure of SELDINGER (Figs. 5 and 6). These contractions could in some cases be seen to diminish when observed for a few hours (Fig. 5).

Fig. 4. Incomplete spasm of brachial artery. Woman aged 50. Tip of catheter high up in the film. Irregular, incomplete contractions, not to be mistaken for arteriosclerosis. Arrow indicates entrance of catheter into artery.

In the series of 20 patients in which the examination was performed with a uniform technique, 17 were comparable. A total contraction around the catheter was seen in 7 of 8 women examined. The length of the contraction varied between 4 and 94 mm with a mean of 40 mm. In 9 men total contraction was seen in only one case and measured 3 mm in length. It was concluded that the tendency for contraction is greater in women than in men. The contractions were seen only in those parts of the vessels where a catheter or a guide had been introduced. It could not be inferred from these earlier mentioned experiments whether the contractions were caused by the guide, the catheter, or both.



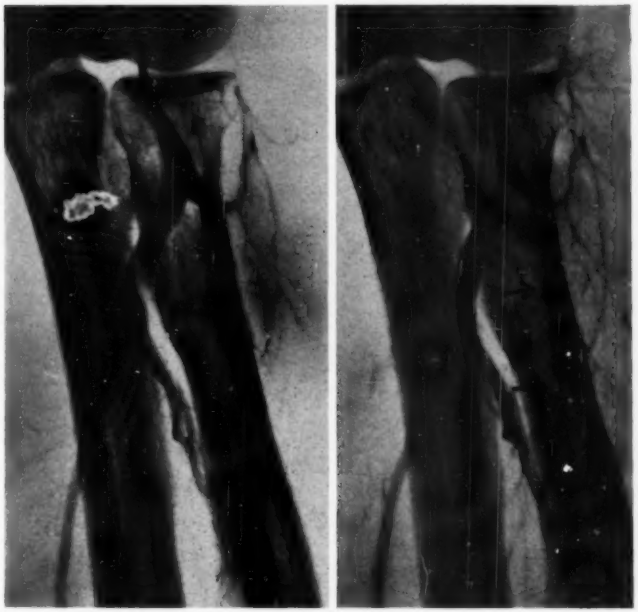
a b c

Fig. 5. Decrease of spasm in thigh arteries caused by a metal guide for catheterization. Girl aged 15. a) Artery into which metal guide has penetrated narrowed by spasm. (↑). Injection through catheter in deep femoral artery. b) Spasm decreased after 10 min. Injection as in a. c) Almost no spasm remains an hour later. Injection through needle in femoral artery.

In 2 cases a catheter was introduced into the subclavian artery in a distal direction. In one of these cases arteriography was performed with the tip of the catheter situated proximally in the upper arm. The arteries in the elbow region had a regular lumen as seen in the films. The catheter was then pushed down to the level of the elbow. A second arteriography disclosed an arterial contraction close to the tip of the catheter. Arteriography of the amputation specimen 9 days later showed a regular lumen (Fig. 7). In the other case a contraction at the tip of the catheter was seen following injection at the level of the elbow; after withdrawal of the catheter approximately 3 cm a further injection disclosed that the contraction had disappeared. The catheter was then pushed in again to the first position and a third arteriography showed the artery to be contracted again at the tip of the catheter (Fig. 8).

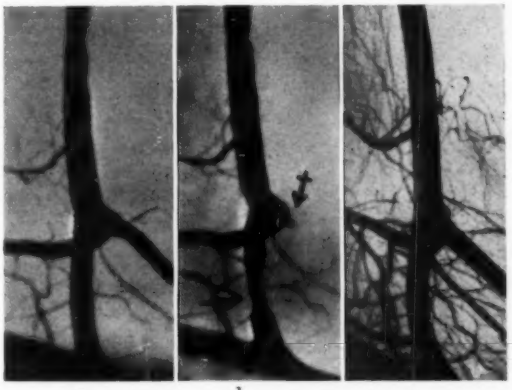
The injection was in these experiments made at low pressure. The conclusion therefore seems warranted that the presence of only the catheter in the lumen is sufficient to provoke spasm.

In one case a catheter was introduced in a distal direction into the proximal part of the brachial artery and arteriography of the lower arm performed with the tip of the catheter situated in the brachial artery at



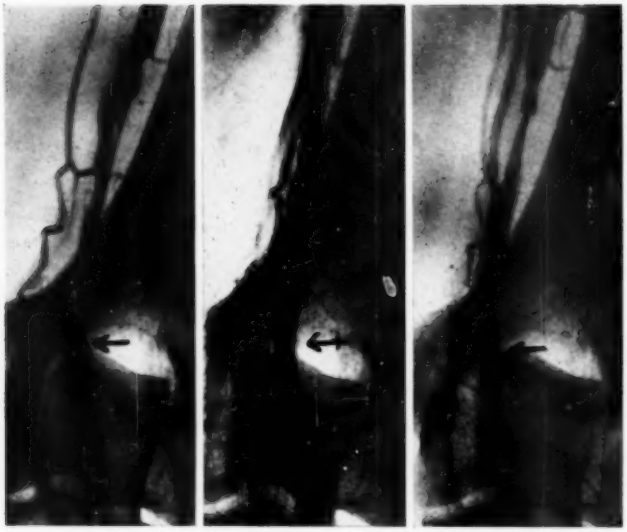
a b

Fig. 6. Spasm in radial artery caused by catheterization with nylon guide. Man aged 43. a) Injection through needle. No narrowing of radial artery. b) Catheter introduced into radial artery and withdrawn to elbow. Spasm provoked in radial artery. (†).



a b c

Fig. 7. Local spasm in brachial artery. Woman aged 33. a) Injection through catheter introduced into subclavian artery with tip proximally in upper arm. No spasm. b) Spasm at tip of catheter (†) which was pushed down from position in a. (Radial artery momentarily occluded by clot (‡).) c) Arteriogram of amputation specimen after 9 days showing that narrowing in b) was functional.



a b c

Fig. 8. Spasm of brachial artery provoked by catheter. Woman aged 54. Three injections with a few minutes interval. Tip of catheter (↑) was retracted from position in a) to position in b) and again pushed back in c). Presence of the catheter caused spasm in a) and c). No spasm in the same region when catheter was retracted (‡).

the middle of the upper arm. The catheter was then pushed in so that the tip entered the interosseous artery almost occluding the lumen of the vessel and contrast medium injected under high pressure. The appearance of the interosseous artery at these two examinations was compared. At the first injection the diameter of the vessel was 1.5 mm and at the second 2 mm. The dilatation was probably due to the high local pressure caused by a powerful injection into a small vessel. At the second injection two contractions of the vessel were seen (Fig. 9). This experiment indicated that a sharp rise of the intraarterial pressure may cause arterial contraction.

Influence of the contrast medium. In the cases with a 'total' contraction the radial pulse disappeared as soon as the catheter had been introduced into the vessel and before the contrast medium was injected. The contractions were often seen to have an identical appearance in several films taken with an interval of up to 10 to 15 minutes. With an ordinary injection pressure contractions were never observed in vessels in which a catheter or a guide had not been introduced; they were always localized to those parts of the vessel where the catheter or the guide was or had been present. The only exception was the case with the forceful injection into the interosseous artery. The contractions therefore did not seem to be caused by irritation from the contrast medium.

a b

Fig. 9. Spasm of interosseous artery probably caused by sudden rise of intravascular pressure. Man aged 53. Catheterization of brachial artery after percutaneous puncture proximally in arm. a) Injection of contrast medium with tip of catheter in middle of upper arm. No spasm in arteries of forearm. Diameter of interosseous artery 1.5 mm. b) Forceful injection into interosseous artery with tip of catheter introduced into vessel causing dilatation and spasm (↑). Diameter of the artery 2 mm.

Discussion

These experiments have shown that spasm is provoked in medium-sized arteries by the presence of an object, *e. g.* a catheter or a metal or nylon guide, in the lumen. Contractions may also be caused by a sharp rise in the intravascular pressure. Such a spasm ordinarily decreases spontaneously within a period probably measuring from half an hour up to some hours. These observations were made on arteries of the extremities. It is however probable that other arteries of the same calibre behave similarly.

Earlier examiners have shown traumatic spasm to be independent of the nerve supply of the vessel. It has also been demonstrated that spasm may be provoked by stretching of the artery.

The mechanism of traumatic arterial spasm has been much debated and the following working hypothesis agrees with previous authentic investigations and my observations. When a sudden stretching of the muscle layer in a normal arterial wall is produced, *e. g.* by an object in the lumen of the vessel, a contraction often arises as a result of direct mechanical stimulation of the smooth muscle. The traumatic segmental spasm in connection with gunshot wounds is presumably caused by stretching of the arterial wall from the great pressure variations in the tissue during the passage of the projectile. A sudden stretching of the brachial artery is likely to occur when a supracondylar fracture occurs. It is furthermore conceivable that an embolus may give rise to stretching of the vessel wall when it is suddenly forced into an artery by the arterial pressure, thus producing spasm. Earlier observations of arterial spasm may be explained with the aid of this hypothesis.

Fibrosis of the medial layer of the arterial wall is generally present in arteriosclerosis. During an earlier work on the arteries of the lower

limb (LINDBOM 1950) it was observed that such fibrosis was common even without marked arteriosclerotic changes in the middle-aged and elderly. Arteries so affected cannot contract. Arterial spasm is thus rarely seen in old and middle-aged patients who form the bulk of the arteriographic material. Extreme contraction can probably not be produced in large elastic arteries, at least not in adults, and marked spasm can be elicited only in the more peripheral predominantly muscular arteries. Spasm is seldom seen at arteriography by means of puncture or catheterization in the subclavian and axillary arteries but this phenomenon is common in the brachial artery and often present in the main arteries of the forearm when a catheter is introduced. In the femoral artery spasm is rarely produced but the difficulty in puncturing the popliteal artery may be due partly to the greater ability of this artery to contract. Arteriographic experience thus indicated that the proneness to spasm probably increases peripherally.

Raynaud's disease is generally regarded as due to spasm in the digital arteries. The greater tendency to arterial spasm in normal females than in normal males which was obvious in this investigation may be one reason why this disease is predominant in women. Arterial spasm may occur also in other pathologic conditions in which the intravascular pressure is suddenly raised.

The arteriographic appearance of arterial spasm is similar to that of irregular intimal thickening generally caused by arteriosclerosis. For the differentiation of these two conditions the following points should be borne in mind. If a catheter or some such object has been or is present in the lumen of the vessel or if a sharp rise of the intravascular pressure has occurred, spasm is likely to arise. When the irregularities diminish or disappear after a while they are due to spasm. In old and/or arteriosclerotic patients spasm is not likely to occur.

Conclusions

Spasm arises normally in medium-sized arteries when the wall of the vessel is stretched by an object in the lumen or by a sharp rise of the intravascular pressure. Such a contraction of the arterial wall seen in arteriography may be mistaken for irregular intimal thickening caused by arteriosclerosis. The arterial wall should therefore be judged arteriographically with great caution in cases in which a catheter or another object is or has recently been present in the lumen, and in which the vessel is suddenly dilated by a forceful injection.

Puncture of arteries should be performed not too far from the heart, where the arterial wall is mainly elastic. In muscular arteries puncture may be difficult owing to spasm.

The mere presence of a catheter in the lumen of an artery may cause the vessel to contract around the catheter thus stopping the blood supply to the region concerned.

Catheters should therefore not be introduced into muscular arteries leading to organs in which a decrease af the blood flow can cause damage, particularly the brain and the heart. Intraarterial catheterization may, however, be performed in the extremities without risk of producing damage and is often useful for arteriography.

SUMMARY

An investigation was carried out in a material of 50 cases to determine the influence of various factors in angiography in producing arterial spasm. It was found that spasm arises in medium-sized arteries when the vessel wall is stretched by an object in the lumen or dilated by a sudden rise in the intravascular pressure. The differentiation between the appearances produced by contraction and those present in arteriosclerosis is discussed.

ZUSAMMENFASSUNG

Ein Material von 50 Fällen ist eingehend untersucht worden, um den Einfluss verschiedener Faktoren auf das Auftreten von arteriellen Spasmen bei der Angiographie zu bestimmen. Man fand, dass in Arterien mittlerer Grösse ein Spasmus auftritt, wenn die Gefässwand von einem Gegenstand im Lumen gestreckt oder durch einen plötzlichen Anstieg des Gefässdruckes erweitert wird. Die Differenzierung zwischen dem Aussehen der durch Kontraktion erzeugten und der bei Arteriosklerose vorliegenden Spasmen wird besprochen.

RÉSUMÉ

L'auteur a effectué sur 50 cas des recherches pour préciser l'influence de divers facteurs sur la production de spasmes artériels dans l'angiographie. Le spasme se produit dans les artères de moyen calibre quand la paroi du vaisseau est distendue par un objet situé dans la lumière, ou quand elle est dilatée par une élévation soudaine de la pression intravasculaire. L'auteur étudie la différenciation entre les images dues à la contraction et celles qui existent dans l'artériosclérose.

REFERENCES

Cohen, Sol. M.: Traumatic arterial spasm. Lancet 1944: I, p. 1.

Gesenius, H.: Über den Spasmus grösseren Arterien. Berl. med. Ztschr. 1 (1950), 302.

Kinmonth, J. B., Simeone, F. A. and Perlow, V.: Factors affecting the diameter of large arteries with particular reference to traumatic spasm. Surgery 26 (1949), 452.

Kinmonth, J. B.: The physiology and relief of traumatic arterial spasm. Brit. M. J. 1952, p. 59.

Kroh, F.: Frische Schussverletzungen des Gefässapparates. Eine klinische-experimentelle Studie. Beitr. z. Klin. Chir. 108 (1917), 61.

KÜTTNER, H., und BARUCH, M.: Der traumatische segmentäre Gefässkrampf. Bruns Beitr. z. Klin. Chir. 120 (1920), 1.

LÄWEN, A.: Arteriospasmus bei akuter massiver Trombose der V. fem. Zentralbl. f. Chir. 61 (1934), 1681.

LERICHE, R.: Physiologie pathologique et chirurgie des artères. Principes et méthodes de la chirurgie artérielle. Masson, Paris 1943.

— Du spasme prolongé des artères. Spasme pur de 4 mois de durée siègeant sur l'artère humérale chez une hypertendue. Presse méd. 51 (1943), 9.

LINDBOM, Å.: Arteriosclerosis and arterial thrombosis in the lower limb. Acta radiol. Suppl. 80 (1950).

MONTGOMERY, A. H. and IRELAND, J.: Traumatic segmentary arterial spasm. J. A. M. A. 105 (1935), 1741.

MUSTARD, W. T. and SIMMONS, E. H.: Experimental arterial spasm in the lower extremities produced by traction. J. Bone & Joint Surg. 35 B (1953), 437.

SCHRADER, E. A.: Spastik und Dilatation den Arterien im Röntgenbild. Ztschr. f. Kreislaufforsch. 40 (1951), 592.

SELDINGER, S. I.: Catheter replacement of the needle in percutaneous arteriography. A new technique. Acta radiol. 39 (1953), 368.

SUTTON, M.: Arterial spasm due to an intravenous infusion. Brit. M. J. 1952, p. 859.

FROM ROENTGEN DEPARTMENT I (DIRECTOR: DOCENT GUNNAR JÖNSSON),
SÖDERSJUKHUSET, STOCKHOLM, SWEDEN

ELECTROKYMOGRAPHIC OBSERVATIONS IN MYXOMA OF THE LEFT ATRIUM

by

Olle Marions and *Per Ödman*

The most common tumours in the left atrium are myxomata and usually arise from the atrial septum or posteriorly in the area between the orifices of the pulmonary veins (PRICHARD, et al.) The tumour is often pediculated to a greater or less degree, by reason of which it may alter in position within the atrium. The myxoma often obstructs the mitral ostium and thus affects the circulation (YATES, et al.) LIKOFF et coll. also suggest the possibility of the tumour blocking the orifices of the pulmonary veins in the atrium.

Occlusion phenomena are often conditioned by posture, so that transitory blockage occurs in certain body positions. This seems to depend on the tumour changing position in the atrium according to as the body position is altered. The outflow and inflow of the atrium is thereby influenced to varying degrees by the tumour, mainly depending on its anatomic position in relation to the mitral ostium and the orifices of the pulmonary veins.

This blocking mechanism is clinically manifest by certain typical symptoms, such as attacks of syncope, cyanosis and dyspnea, occurring in certain body positions. Furthermore, in most cases the character of the mitral murmurs are markedly altered by changes in posture. If such symptoms are present, a tumour of the left atrium should be suspected. However, these indications only allow a probable diagnosis. A definite diagnosis can only be made with angiocardiography (STEINBERG et coll.; GOLDBERG et coll., and others).

Two cases of myxoma in the left atrium which the authors have studied were diagnosed with selective angiocardiography ad modum JÖNSSON et coll. with contrast medium injected into the pulmonary artery.

Submitted for publication 14 November 1956.

Case 1. The tumour filled a large part of the atrium. During atrial systole it was observed that the atrium contracted almost completely around the filling defect representing the myxoma. Thus, during atrial systole it was surrounded by a thin contrast layer of about 2 mm. During diastole this contrast margin was between 1 and 2 cm broad. The myxoma made no noticeable cyclical movements in the atrium. The patient was operated on and a polypous tumour was found, measuring approximately 5 cm in diameter. This originated in the posterior wall of the atrium behind the orifice of the pulmonary veins. At the operation one could feel that the tumour dipped down against the mitral ostium during certain phases of the cardiac cycle. The mitral ostium was somewhat constricted, indicating mitral stenosis. Post-operative investigations were not possible, as the patient died immediately after the operation.

Case 2. This patient with myxoma in the left atrium had a smaller tumour which occupied considerably less space in the atrium than in the previous case; the diameter of the growth was approximately 4 cm. From the angiocardiographic study, one could see how the tumour changed position in the atrium according to the different phases of the cardiac cycle. The contrast margin round the tumour was, except in the direction of the mitral ostium, relatively broad (1 to 2 cm) during the whole cardiac cycle; in certain phases the tumour came to lie close up against the mitral ostium. On operation, a pedunculated, polypous tumour with a broad base and originating from the atrial septum at the foramen ovale was found. It was noted by palpation that the tumour blocked the mitral ostium in certain cardiac phases, very much like a ball valve. There was no mitral stenosis. The tumour was successfully removed. The patient survived the operation and is at present free from symptoms.

The electrokymographic findings in these two cases were of special diagnostic value and were well consistent with the angiocardiographic and operation findings.

Electrokymographic examination of the left atrium has been carried out in various body positions. Electrocardiograms and sometimes phonocardiograms have been used as reference curves and that portion of the curve in the atrial electrokymogram representing the contraction of the atrium has been closely studied; it is referred to in this paper as the 'atrial contraction descent'. All values stated for the duration of the atrial contraction descent refer to recording over the left auricular appendage.

According to ANDERSON, DEUTSCH et coll., ÖDMAN, and others, the duration of the atrial contraction descent in normal subjects does not exceed 0.10 sec, when recording takes place over the auricular appendage with the patient erect. This applies both to the left and to the right atrium.

An abnormally prolonged atrial contraction descent with a relatively large amplitude reflects an extra-strong atrial contraction (LUISADA, ÖDMAN). Hemodynamically, this implies that a relatively large volume of the blood in the atrium must be expelled into the ventricle by the contraction of the atrium. Such a circulatory condition exists, for example, when excessively large amounts of blood are to pass through the atrium to the ventricle, as well as when the mitral ostium is constricted or the

Fig. 1. Normal subject. Left auricular appendage electrokymograms. a) Erect. Atrial contraction descent (↑↑) is descending, and its duration 0.07—0.08 sec. Rapid inflow downstroke (↕↕) has larger amplitude than the atrial contraction descent. Compare Fig. 2b. b) Supine. Atrial contraction descent has larger amplitude than in sitting position. Its duration is also longer — 0.12 sec.

emptying of the atrium is impeded for some other mechanical reason. Similar circulatory alterations also manifest themselves electrokymographically as a comparative reduction of the part of the curve that represents the rapid inflow phase, referred to as the 'rapid inflow downstroke' (Fig. 1 a). In such cases the curve usually also follows a relatively horizontal course during diastole, a phenomenon which is called the 'diastolic plateau' (Fig. 2 b).

Seven subjects with normal hearts and seven with mitral stenosis have been examined electrokymographically in the same way as the cases with a tumour in the left atrium, and form the comparison material. In all these cases the atrial contraction descent was shorter and of smaller relative amplitude in the sitting position than when the examination was carried out with the patient supine, regardless of whether the duration was normal or not (Figs. 1 and 2, and Table 1).

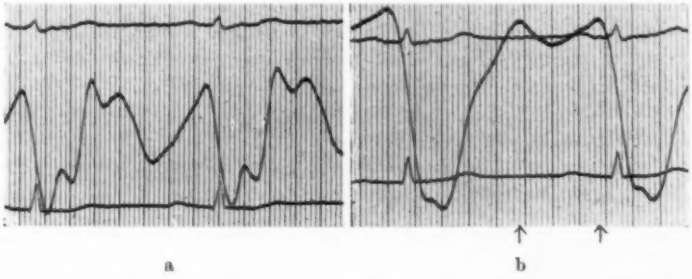
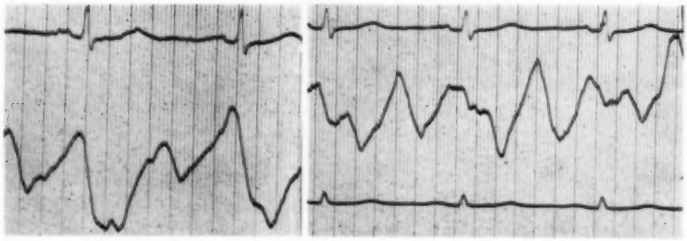


Fig. 2. Mitral stenosis. Left auricular appendage electrokymograms. a) Erect. Atrial contraction descent duration: 0.11 sec with relatively large amplitude. b) Supine. Atrial contraction descent duration is longer (0.13—0.14 sec) than in upright position. Its relative amplitude is also larger. The rapid inflow downstroke has a level course, so that, during diastole, the curve is almost horizontal — 'diastole plateau' (↑↑).



a b

Fig. 3. Case 1. Myxoma of left atrium. Left auricular appendage electrokymograms. a) Erect. Atrial contraction descent prolonged with a duration of 0.12 sec, and with a relatively large amplitude. b) Supine. Atrial contraction descent of considerably shorter duration (0.08 sec) than in sitting position and of relatively much smaller amplitude.

RUDHE has made more or less the same observations regarding the behaviour of the atrial contraction descent in recordings made over the right atrium in different body positions. His results are based on examinations of cases in which the atrial contraction descent had both normal and prolonged durations in the sitting posture. The cases which had a pathologically long atrial contraction descent consisted of 4 with a high degree of valvular pulmonary stenosis and 3 with infundibular stenosis.

It thus appears as if the atrial contraction descent is generally prolonged on examination in the recumbent as compared with the upright position.

In Case 1, the atrial contraction descent was descending and prolonged (0.12 sec) with a relatively large amplitude on examination in the sitting position. It was also descending but considerably shorter, with a duration of 0.08 sec, with the patient supine (Fig. 3 and Table 1); its amplitude was also much smaller. The electrokymogram of the left atrium did not otherwise deviate noticeably from the normal either in the supine or sitting positions. One might have expected a considerable prolongation of the atrial contraction descent on examination in the supine position. Such was, at any rate, the case with the cases of mitral stenosis examined in this way. The discrepancy must be attributed to the concomitant myxoma in the atrium. The tumour occupied a large part of the atrial cavity, so that the volume of blood in the atrium was lessened accordingly. Furthermore, there is the possibility that the tumour hindered the inflow from the pulmonary veins to the atrium. This mechanism has probably asserted itself most in the supine position as, from the angiocardiographic examination carried out in this position, it was evident that the tumour lay close against the orifices of the pulmonary veins.

Table I

Duration of 'atrial contraction decent'

(Recorded over the left auricular appendage)

	Sitting position	Supine position	The difference in each individual case amounted to
Normal subjects (7 cases)	0.04—0.08 sec	0.06—0.12 sec	0.02—0.06 sec
Mitral stenosis (7 cases)	0.10—0.12 sec	0.12—0.14 sec	0.02—0.04 sec
Case 1: myxoma in the left atrium	0.12 sec	0.08 sec	
Case 2: myxoma in the left atrium (pre-operative)	0.11 sec	0.11 sec	
Case 2: myxoma in the left atrium (post-operative)	0.04 sec	0.08 sec	

The effect of the mechanism discussed is, among other things, likely to be that the amount of blood passing through the atrium is reduced. It is possible that this has an effect on the emptying of the atrium, so that the volume of blood which passes into the ventricle through the contraction of the atrium itself, is relatively small. This is reflected electrokymographically on the atrial contraction descent. In Case 1 it was not so prolonged as in cases of mitral stenosis with no concomitant tumour (Table 1). On examination in the sitting position, the atrial contraction descent was considerably longer than normal (Fig. 3 a), with a relatively very large amplitude, indicating that the circulatory conditions were different from those present in the supine posture.

In Case 1, the duration of the 'atrial contraction descent' on examination in different body positions, differed from that observed in RUDHE's study and our comparison material. This clearly suggests that the myxoma influences the circulatory conditions in a decisive way when the patient is sitting. The angiocardiographic examination and, above all, the findings at operation, indicate that the tumour obstructed the mitral ostium. To judge from the size, structure, and anatomic position of the myxoma, the occluding effect was most deleterious in the sitting position. In this posture, the tumour hung straight down against the mitral ostium where, because of its size, it could obstruct the entire opening; furthermore, the orifices of the pulmonary veins probably became free, which increased the inflow to the atrium. Because of this latter effect, the blood volume which was to pass through the atrium became greater in the sitting than in supine position. The above-mentioned mechanisms, and in particular the blocking effect of the tumour, so influenced the emptying of the atrium that its contraction activity was increased in the sitting position. This was reflected in the electrokymogram in that the atrial contraction descent in this position had a considerably longer duration with a relatively greater amplitude than that recorded when the patient was supine.

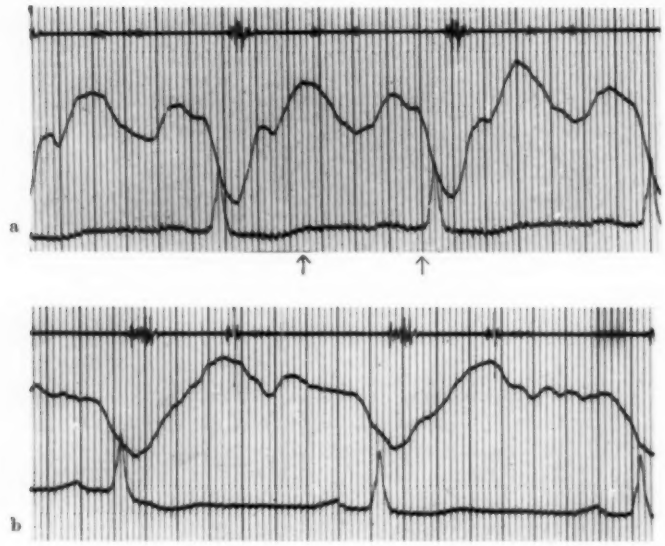


Fig. 4. Case 2. Myxoma of the left atrium. Pre-operative left auricular appendage electrokymograms. *Above:* Phonocardiogram. *Below:* Electrocardiogram. a) Erect. Atrial contraction descent somewhat prolonged (0.11 sec). Slight indication of diastolic plateau (↑↑). b) Supine. Atrial contraction descent of same duration as in sitting position. Diastolic plateau.

It was in other words possible by means of the electrokymographic examination to demonstrate objectively the postural symptoms that characterise myxoma in the left atrium.

In Case 2 the atrial contraction descent was somewhat prolonged, with the same duration on recording in the sitting as in the supine position. The rapid inflow downstroke also had a relatively small amplitude, and furthermore, a diastolic plateau was recorded (Fig. 4 a and b). These variations were observed on examination both in the sitting and supine positions.

On post-operative examination, the electrokymogram had altered considerably. The atrial contraction was still descending in recordings obtained both in the sitting and supine positions. Its amplitude, however, was smaller this being particularly apparent on examination in the sitting position. Its duration had also shortened, but to different degrees, so that it was shorter in the sitting than in the supine position (Fig. 5 and Table 1). In other respects the postoperative electrokymogram did not differ from the normal. The variation between the pre- and post-operative electrokymograms indicates that the tumour interfered with the atrial

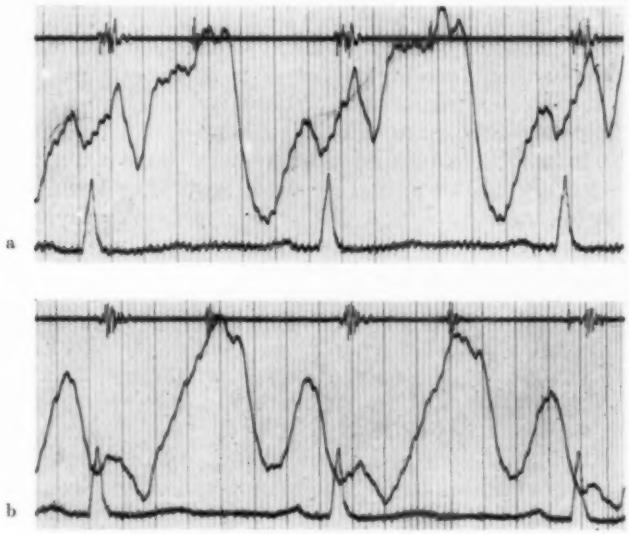


Fig. 5. Case 2. Myxoma of left atrium. Post-operative left auricular appendage electrokymograms. *Above:* Phonocardiogram. *Below:* Electrocardiogram. a) Erect. Atrial contraction descent of relatively smaller amplitude than before operation with duration much shorter (0.04 sec). Curve otherwise normal. b) Supine. Atrial contraction descent of slightly shorter duration than before operation; on the other hand longer than in sitting position after operation.

hemodynamics to a high degree. Before operation there were changes in the curve indicating that evacuation of the atrium was disturbed and, to judge from the angiocardiographic as well as the operation findings, the reason appears to have been the blockage of the mitral ostium by the tumour. On the other hand, there seemed little likelihood that the myxoma was blocking the orifices of the pulmonary veins. The contrast margin between the tumour and the posterior wall of the atrium was 1 to 2 cm, according to the angiocardiographic appearances, irrespective of the cardiac phase. Furthermore, the tumour was comparatively smaller than in Case 1; for that reason, the obstruction of more than one orifice hardly comes into the question.

Posturally conditioned occlusion to the extent shown in Case 1 hardly existed in Case 2, to judge from the electrokymographic findings, although a tendency to increased blocking may be traced in the sitting as compared with supine position. The atrial contraction descent was somewhat prolonged in the former, indicating a slightly stronger atrial contraction than usual. The duration was not lengthened in the supine position

recording (Fig. 4), as could regularly be seen in the comparison material. On the other hand, at the post-operative examination, the duration of the atrial contraction descent was longer in this posture than in the other (Fig. 5), *i. e.* the same phenomena as observed in RUDHE's investigations and in our comparison material.

The interpretation of these observations must be that the atrial contraction before operation was stronger in the sitting than in the supine position. After operation the atrial contraction activity had diminished. No postural influences other than the usual ones were observed.

Conclusions

Electrokymography in cases of myxoma in the left atrium enables information about the specific circulatory conditions prevailing in this chamber of the heart to be obtained. The electrokymogram should be recorded in different body positions over the auricular appendage. The so-called paroxysmal mitral occlusion due to posture is revealed, inter alia, by this means.

ACKNOWLEDGEMENT

The authors express their thanks to Drs. S. R. KJELLBERG and U. RUDHE of the Paediatric Roentgendiagnostic Department of Karolinska Sjukhuset for permission to publish Case 2.

SUMMARY

Two cases of myxoma in the left atrium have been examined electrokymographically in the sitting and supine positions. Blocking phenomena, especially those conditioned by posture, appear to be reflected in the electrokymogram of the left atrium.

ZUSAMMENFASSUNG

Zwei Fälle mit Myxom des linken Vorhofes sind elektrokymographisch in sitzender und liegender Stellung untersucht worden. Blockierungsphänomene, besonders die durch die Körperstellung hervorgerufenen, scheinen in das Elektrokymogramm des linken Vorhofes reflektiert zu werden.

RÉSUMÉ

Les auteurs ont examiné électrokymographiquement deux cas de myxome de l'oreillette gauche, en position assise et en décubitus. Les phénomènes de blocage, en particulier ceux qui sont conditionnés par la position, se traduisent manifestement sur l'électrokymogramme de l'oreillette gauche.

REFERENCES

ANDERSSON, T.: Electrokymographic examinations in mitral valve disease. Acta radiol. Suppl. 106 (1953).

DEUTSCH, E., GMACHL, E., SCHACHINGER, H., SIEDEK and WEGNER, R.: Die Elektrokymographie. Ztschr. f. Kreislaufforsch. 40 (1951), 129.

GOLDBERG, H. P., and STEINBERG, I.: Primary tumors of the heart. Circulation 11 (1955), 963.

JÖNSSON, G., BRODÉN, B. and KARNELL, J.: Selective angiocardiography. Acta radiol. 32 (1949), 486.

LIKOFF, W., GECKELER, G. D. and GREGORY, J. E.: Functional mitral stenosis produced by an intra-atrial tumor. Am. Heart J. 47 (1954), 619.

LUISADA, A. A.: Atrial phenomena. Proc. First Congress of Electrokymography 1950. U. S. Public Health Service Publication No. 69, p. 53. Washington 25, D. C., 1951.

ÖDMAN, P.: Electrokymographic studies of normal and abnormal right auricles. Acta radiol. 44 (1955), 353.

PRICHARD, R.: Tumors of the heart. Review of the subject and report of 150 cases. Arch. Path. 51 (1951), 98.

RUDHE, U.: Electrokymography with special reference to valvular pulmonary and infundibular stenosis. Acta radiol. Suppl. 134 (1956).

STEINBERG, I., DOTTER, C. T. and GLENN, F.: Myxoma of the heart, roentgen diagnosis during life in three cases. Dis. Chest. 24 (1953), 509.

YATES, W. M.: Tumors of the heart and pericardium; pathology, symptomatology, and report of nine cases. Arch. Int. Med. 48 (1931), 627.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: DOCENT BENGT S. HOLMGREN), SABBATSBERGS SJUKHUS, STOCKHOLM, SWEDEN

A MODIFIED CATHETER FOR PERCUTANEOUS ANGIOGRAPHY

by

Gunnar Tornvall

For the injection of the contrast medium in angiographies a number of techniques have been used (1, 3, 5, 7, 10, 11).

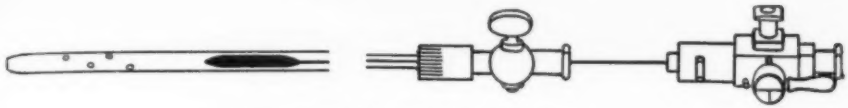
In the percutaneous catheterization method described by SELDINGER, a blood vessel is punctured with a special needle through which a flexible metal leader is introduced into the vessel. The puncture needle is thereafter withdrawn, and the catheter is inserted around the metal leader. After insertion of the catheter, the metal leader is also removed.

One of the advantages of this method is that only a small puncture is needed, the size of the needle being of the same external diameter as the catheter. The ordinary polyethylene catheters are not radio-opaque, however, and it is necessary to ensure that the tip of the catheter is placed in a satisfactory position; either a small amount of contrast medium is injected and a trial exposure is made, or the metal leader is inserted under fluoroscopic control.

In aortographies, the catheter is introduced via one of the femoral arteries, and the contrast medium is injected against the blood stream in the aorta. Under certain conditions the tip of the catheter may recoil during the injection and be displaced to a position which is difficult to predict.

In angiographies, tip-occluded catheters with lateral apertures close to the extremity have proved to eliminate the recoil effect and to afford a more even dispersion of the contrast medium (5, 8). In order to obtain the same advantages when performing percutaneous angiographies, a modified catheter, now described, has been used.

Submitted for publication 5 February 1957.



A. Insertion of the tip-occluding leader.

B. The catheter adapted for injection.

Fig. 1. Schematic drawing of the catheter and tip-occluding leader.

The tip of a polyethylene catheter No. 205 (internal diameter 1.52 mm external diameter 2.08 mm) is slightly tapered and at about 2 to 3 cm from the extremity a small area of the catheter is perforated with 4 holes of 1 mm diameter situated at right angles. For ejection of the contrast medium through the side apertures, the tip of the catheter is occluded by means of a special leader consisting of a thin metal wire (0.5 mm diameter) which for a distance of 2 cm at one end is increased to a diameter somewhat less than the bore of the catheter. The other end of the metal wire is attached by means of an 'adaptor' between the catheter and the injection syringe. The degree of narrowing of the lumen of the catheter caused by the wire of the leader is relatively small, the internal cross-section being reduced by about 10 %. The length of the polyethylene catheter is adjusted to the size of the tip-occluding metal leader (Fig. 1).

The following procedure has been adopted for the injection. After the catheter has been inserted it is filled with a 5 per cent heparin solution to prevent clotting; the tip-occluding metal leader is then introduced under fluoroscopic control. The thickened portion should be placed 2 to 3 cm above the level at which the contrast medium is to be injected.

The method has been tested in four aortographies in which a manual pressure syringe has been used (6). The new technique does not involve any lengthy or difficult procedure.

The catheter is supplied by Stille-Werner Co, Stockholm, Sweden.

SUMMARY

A new catheter for percutaneous angiography is described.

ZUSAMMENFASSUNG

Ein neuer Katheter für perkutane Angiographie wird beschrieben.

RÉSUMÉ

L'auteur décrit un nouveau cathéter pour angiographie percutanée.

REFERENCES

1. Donald, D. C., Kesmodel, K. F., Rollins, S. L. & Paddison, R. M.: An improved technique for percutaneous cerebral angiography. Arch. Neurol. and Psychiat. 65 (1951), 508.
2. Edholm, P. & Seldinger, S. E.: Percutaneous catheterization of the renal artery. Acta radiol. 45 (1956), 15.
3. Fariñas, P. L.: A new technique for the arteriographic examination of the abdominal aorta and its branches. Am. J. Roentgenol. 46 (1941), 641.
4. Fernström, I.: Arteriography of the uterine artery. Acta radiol. Suppl. 122 (1955).
5. Gidlund, Å.: Development of apparatus and methods for roentgen studies in haemodynamics. Acta radiol. Suppl. 130 (1956).
6. Jönsson, G., Brodén, B. & Karnell, J.: Thoracic aortography. Acta radiol. Suppl. 89 (1951).
7. Lindgren, E.: Technique of abdominal aortography. Acta radiol. 39 (1953), 205.
8. Nordenström, B.: Temporary unilateral occlusion of the pulmonary artery. Acta radiol. Suppl. 108 (1954).
9. Ödman, P.: Percutaneous selective angiography of the main branches of the aorta. Acta radiol. 45 (1956), 1.
10. Peirce, E. C.: Percutaneous femoral artery catheterization in man with special reference to aortography. Surg., Gynec. & Obst. 93 (1951), 56.
11. Radner, S.: Intracranial angiography via the vertebral artery. Preliminary report of a new technique. Acta radiol. 28 (1947), 838.
12. Seldinger, S. E.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 368.

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT B (DIRECTOR: DOCENT N. P. G. EDLING), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

ON RENAL DAMAGE DUE TO AORTOGRAPHY AND ITS PREVENTION BY RENAL TESTS

With reports of five cases of severe renal damage

by

Nils P. G. Edling and *C. G. Helander*

During the past few years cases of renal damage due to injection of contrast media into the aorta have been published. The renal failure was in most cases transitory and the incidence is not high, although there are severe or fatal cases among those reported.

The causes of renal complications from aortography described in the literature are of different types. Mostly, too large doses of contrast medium have been introduced. The injection has either been carried out rapidly to produce high concentration of contrast medium in the aorta at the level of the renal arteries (MILLER et coll. 1954, ALWALL et coll. 1955, RICHES & GRIFFITHS 1955), or unintentionally directly into one of the renal arteries (LARSSON & PALMLÖF 1952, HARWARD 1953, JOSSELSON & KAPLAN 1954, MILLER et coll. 1954, ALWALL et coll. 1955, WEYDE 1955, IDBOHRN 1956). In some cases repeated injections have been given (MILLER et coll. 1954, ALWALL et coll. 1955, WEYDE 1955, IDBOHRN 1956).

Severe renal failure is also caused by angiography of kidneys with impaired function (JOSSELSON & KAPLAN 1954, THOMSEN & HANSEN 1954, WEYDE 1955), or by examination of patients whose general condition is poor (KUNLIN et coll. 1950).

According to OLSSON (1955), in aortography a dose of 20 ml of a 60 % solution, when using a diodone organic compound, and of 20 ml of a 50 % solution, when using a triiodone organic compound, should not be exceeded.

In a material of 320 aortographies at Karolinska Sjukhuset 13 patients with reactions of the kidneys are recorded. In 8 of these no subjective side-effects but signs of mild renal insufficiency were noted, *i. e.* slight,

Submitted for publication 21 January 1957.

quickly subsiding, proteinuria in six cases, slight proteinuria, oliguria and an increase of N. P. N. in the blood, promptly reversible, in one case, and a slight increase of N. P. N. for two weeks in one case. In the remaining 5 there was severe impairment of renal function, and these will be briefly reported.

The first patient was a 33-year-old woman with placenta praevia. Pelvic arteriography with compression of the femoral arteries was performed twice by injection *ad modum* SELDINGER, 50 ml Umbradil 50 % being injected on each occasion into the aorta high above the bifurcation. On both occasions a marked nephrographic effect was produced. Anuria-oliguria and proteinuria subsequently developed, and the blood level of non-protein nitrogen was elevated. After five days the urinary volume was normal and nine days later there was no proteinuria and the N. P. N. level was normal. The highest N. P. N. value measured was 120 mg per 100 ml.

The second patient was a 24-year-old woman suspected of extra-uterine pregnancy. She had no proteinuria before angiography. 40 ml and 30 ml Umbradil 50 % and 70 %, respectively, were injected *ad modum* SELDINGER 18 cm and 30 cm above the groin (compression of the femoral arteries); only the pelvic vessels were examined. After the examination side-effects occurred, and anuria-oliguria, proteinuria, reduced specific gravity of urine and increased N. P. N. in the blood were present. After a fortnight the urinary volume was normal — there was no proteinuria. Ten days later the non-protein nitrogen content of the blood was normal; the highest level had been 200 mg per 100 ml. Two months after the examination the maximum specific gravity of the urine was still 1.016.

The third patient was a 49-year-old man with intermittent claudication. Oscillography showed very small pulsations in the upper legs, indicating changes in the lower aortic branches. On admission there was no proteinuria and the N. P. N. level was normal. At aortography 30 ml Umbradil 70 % was injected after direct percutaneous puncture of the aorta at the level of L 1. The films demonstrated an abrupt occlusion of the aorta immediately below the origin of the renal arteries; most of the contrast medium had entered into these vessels, producing an intense nephrographic effect. After the examination subjective side-effects, oliguria, proteinuria, reduced specific gravity of urine, and increased N. P. N. in the blood, appeared. A week later the patient's general condition was again good, the urinary volume normal, and there was no proteinuria. After 2 ½ weeks the N. P. N. level was normal; the highest value had been 172 mg per 100 ml. The concentrating power of the kidneys was not followed up.

The fourth patient was a 37-year-old woman with recurrent cystopyelonephritis (papillary necrosis). Before the aortography she had proteinuria and the N. P. N. level was 44 mg per 100 ml. The amount of contrast medium used at aortography was not recorded. After the examination the patient's general condition for a time was bad, and the N. P. N. level was elevated for at least ten days; the highest value was 83 mg per 100 ml. There was no proteinuria. At an examination five months later the N. P. N. level was normal.

The fifth patient was a 58-year-old woman with a large cyst at the upper pole of the right kidney, extending beneath the liver. Two months previously she had had slight proteinuria and the N. P. N. level was 48 mg and 41 mg per 100 ml on two separate occasions. Because of pain in the right hypochondrium urography (20 ml Umbradil 50 %) was performed without complications, followed by aortography and cyst puncture 11 and 13 days later.

At the aortography nearly 40 ml Umbradil 70 % was injected *ad modum* SELDINGER at a rapid rate 30 cm above the groin. An intense nephrographic effect

occurred bilaterally, and in the right kidney an additional defect at the upper pole was noted. On the following day the patient's general condition deteriorated. For localization of the renal pelvis for the cyst puncture 2 × 20 ml Umbradil 50 % were injected intravenously. Despite the large dose no excretion of contrast medium occurred. Anuria-oliguria, proteinuria, a decrease in specific gravity, and raised blood level of non-protein nitrogen (maximum 163 mg per 100 ml) were noted in addition to the subjective symptoms. The urinary volume returned to normal after three weeks. The proteinuria lasted for two months and there were traces of protein in the urine seven months later. The N. P. N. level was normal after four months. Over a period of seven months the specific gravity of the urine did not exceed 1.017.

In the first two of these five cases the examinations were performed with repeated large doses of contrast medium injected into the aorta. In both cases the femoral arteries were compressed to assure complete filling of the pelvic arteries. But the contrast medium also entered the renal arteries in amounts sufficient to cause renal damage. The untoward signs cleared up completely in one case, in the other there was lasting impairment of the ability of the kidneys to concentrate.

In the third case most of a moderately large but highly concentrated dose of contrast medium intended for the aorta passed into the renal arteries owing to occlusion of the distal part of the aorta. The signs of renal damage disappeared completely.

In the remaining two cases the function of the kidneys was impaired before aortography was performed. In one of them, moreover, the amount of contrast medium was large and the injection performed very quickly. In this case the severe reactions lasted for months, and impairment in the concentrating power of the kidney persisted; in the other case the signs cleared up completely.

Thus, in our material renal failure after aortography seemed to be due to large, or large repeated, doses of contrast medium in three cases. Impaired renal function was the primary cause in one case, and a large dose of contrast medium and impaired kidney function in another case.

In addition there are two cases with complications after aortography in which it is clinically impossible to judge whether or not these were caused by the roentgenologic investigation.

In the first case (urogenital tuberculosis) aortography was performed with 30 + 30 ml Umbradil 70 % two days after a protracted and difficult cystoscopic examination. On the day following the aortography the N. P. N. level had risen from normal to 50 mg per 100 ml. No subjective side-effects were reported. Seventeen days after the aortography the patient underwent a nephrectomy. For a fortnight after the latter intervention the N. P. N. level increased; the highest value was 117 mg per 100 ml. Such a great increase is unusual after nephrectomy; it is, however, impossible to distinguish between the role of the roentgenologic investigation and that of the surgical intervention.

In the second case the patient had a large pancreatic cancer with metastases into the abdominal glands. His general condition was relatively good but he had dyspnoea at night. The N. P. N. level was normal. After aortography with two injections of con-

trast medium (the amounts were not recorded) his general condition deteriorated; the N. P. N. level increased to 52 %. One week later he died. At necropsy sectioning of the kidneys revealed macroscopically normal surfaces. In this case in which a pancreatic tumour with metastases was accompanied by cardiac insufficiency, it is probable that any intervention would have been fraught with danger to the patient; celiotomy, we were informed by the physicians, was also contraindicated.

Renal angiography is a major examination which involves a great strain on the kidneys. The indications should therefore, be carefully assessed and the renal function of the kidneys should be examined previous to the injection of contrast medium.

For measuring the different processes in renal function — glomerular filtration, tubular reabsorption, tubular excretion and tubular synthesis — various tests may be used.

The glomerular filtration rate is identical with the inulin clearance and can therefore be quantitatively measured exactly. However, an accurate measurement of inulin clearance is a complicated method and is only carried out in research clinics at the present time. Urea is also used in quantitative measurements of glomerular filtration, despite the fact that a variable portion diffuses back through the tubular walls. Carefully performed urea clearance provides good information of renal function and is easily carried out; it is the most frequently used clearance test in general ward service. Creatinine clearance is also taken to be measure of glomerular filtration but is not identical with it, since creatinine is also eliminated by tubular excretion; moreover it is a more complicated test than the urea clearance. The blood level of non-protein nitrogen is an indirect measure of glomerular filtration. Estimation of non-protein nitrogen is generally used but is of less value because the level does not begin to rise noticeably until the active kidney tissue is reduced to about half of its original amount (McKay & McKay 1927); Johnstone (1930—1931) has found normal figures despite the fact that about 80 per cent of the functional capacity of the kidneys is lost.

Reabsorption of water in the distal parts of the tubules is measured by the specific gravity test. It is of great value and easy to perform and hence the most frequently used test in general practice.

Tubular excretion can be measured by the phenolsulphonphthalein (phenol-red) test. This dye is eliminated to a much greater extent by tubular excretion than by glomerular filtration; it is a simple but unreliable test. Diodrast or PAH clearance, on the other hand, is virtually an exact measure of the effective renal plasma flow (when present in the blood in a low concentration), and of the maximal rate of renal excretion. The complicated technique has restricted the method to research.

None of the methods of estimating *tubular synthesis* has attained any practical importance.

Tests of the bladder urine or on the blood show total renal function; for selective study of each kidney a specimen of ureteral urine should be used.

Urography is also often employed as a test of renal function. The difference in value of urography and clearance as tests of renal function is demonstrated in a material published by the present authors et coll. (1956). That investigation showed that urography — in itself a qualitative test — cannot replace quantitative tests when an exact measure of renal function is necessary.

Of the methods for testing renal function, the specific gravity test, the urea clearance, and the estimation of non-protein nitrogen in the blood are easy to perform and most commonly used in clinical work. The two first-mentioned tests, in particular, are of great value in examinations prior to renal angiography.

In the literature increasing attention is being paid to the examination of renal function before and after renal angiography. TRAUTNER & PAHLE (1954) have published nine cases in which the total renal function was closely studied before and after renal angiography. Their investigations comprised examinations of the pulse, blood pressure, urinary sediment, plasma CO_2, serum chlorides, serum proteins as well as the Addis test, blood urea, and 24-hour creatinine clearance. According to the same principles LODIN & THORÉN (1955) have systematically performed tests of renal function before and after 15 aortographies. In 1956 IDBOHRN published a series of 200 patients examined by renal angiography, who had been subjected to certain tests of total renal function before and after the examination. He recommends estimation not only of non-protein nitrogen but also of the maximal concentrating power of the kidneys, which should be at least 1.020.

In assessing the value of the different tests with regard to the function of the kidneys the following facts should be considered.

Like most other organs the normal kidney has a large factor of safety and can cope with an excretory load that is much greater than that present in the ordinary course of life, for example a renal arteriography performed according to established procedures. With respect to the reserve power of the kidneys three stages of functional impairment may be differentiated. In the first latent stage the impairment is so slight that it merely narrows the factor of safety. This stage can only be demonstrated by means of tests of renal function; there are very slight changes in specific gravity and in clearance tests. The second stage, called compensated impairment of renal function, is characterized clinically by true changes in specific gravity and in clearance tests. Reten-

tion of urinary constituents does not yet occur. In the third decompensated stage of impairment of renal function the kidneys fail to manage the excretory load with resultant retention of urinary constituents in the blood. Only at this stage can an increase in the non-protein content of the blood be demonstrated.

With respect to the factor of safety the patients who are sent to the roentgen department for renal angiography may also be divided into groups according to the risks.

The first group includes kidneys with normal functional capacity which show normal concentrating power on specific gravity test (above 1.026). In these cases the factor of safety is intact, and a renal angiography performed according to established procedure may be carried out.

To the second group belong cases in which the concentrating power of the kidneys is between about 1.026 and 1.020. This group requires more careful and thorough examination, and the specific gravity test should be followed by the urea clearance test. If the specific gravity approaches 1.020 and the urea clearance half the normal value, the indications for renal angiography should be carefully assessed and the examination performed with great caution. In such cases there is severe renal disease and an extra load would involve great risks.

The third group consists of patients in the decompensated stage of impaired renal function with an increase in the non-protein nitrogen in the blood, and greatly reduced urea clearance. In these cases there is true renal insufficiency and renal angiography is contra-indicated.

Some important points must be considered before a nephrectomy. If the total functional capacity of the kidneys is good, that is, if the ability to concentrate is above 1.026, further examination of the functional capacity seems unnecessary. However, in patients whose total renal function is subnormal there are indications for selective qualitative tests of the kidney which is not to be excised and which will have to carry the whole functional load after contralateral nephrectomy. After clearances of ureteral urine selective angiography of the kidney to be excised should be performed by means of a catheter introduced percutaneously with positioning of the tip (EDHOLM & SELDINGER 1956, ÖDMAN 1956).

When angiography of a solitary kidney is indicated, the study of function should be done by accurate measurements of clearance, even if the concentrating power is normal. Clearance figures which indicate a capacity twice the normal show that renal angiography may be safely performed. If the figures indicate a capacity of only one kidney or less, renal angiography is contra-indicated.

The following case will serve as an example of examination according to the principles discussed above.

The patient had a solitary kidney after nephrectomy 21 years previously which at urography had excreted normally. He was admitted with a retroperitoneal tumour to be investigated with respect to its position in relation to the inferior vena cava and the aorta. Previous to aortography clearance examinations were performed: $C_{in}125$, C_{PAH} 855 ml per minute. These figures showed that the functional capacity of the remaining kidney was twice the normal, and thus that aortography could be safely performed. By SELDINGER's technique 45 ml Rheopak 40 % were injected into the aorta at the level of the suprarenal areas. A moderate nephrographic effect was noted. No subjective or objective reactions occurred.

SUMMARY

The authors discuss renal damage by aortography, with a report of five cases, and the principles in preventing it.

ZUSAMMENFASSUNG

Die Verfasser diskutieren Nierenschädigungen bei der Aortographie sowie die Richtlinien für deren Vermeidung. Sie berichten über 5 Fälle.

RÉSUMÉ

Les auteurs étudient les troubles rénaux dus à l'aortographie; ils en rapportent cinq cas et indiquent les principes de la prévention de ces troubles.

BIBLIOGRAPHY

ALWALL, N., JOHNSSON, S., TORNBERG, A. & WERKÖ, L.: Acute renal failure following angiography. Acta chir. Scandinav. 109 (1955), 11.

EDLING, N. P. G., EDVALL, C. A., HELANDER, C. G. & PERNOW, B.: Comparison of urography with selective clearance as tests of renal function. Acta radiol. 45 (1956), 85.

EDHOLM, P. & SELDINGER, S. I.: Percutaneous catheterization of the renal artery. Acta radiol. 45 (1956), 15.

FISHBERG, A. M.: Hypertension and nephritis. Lea & Fibiger, Philadelphia 1954.

HARWARD, M.: Renal angiography. J. Urol. 50 (1953), 15.

IDBOHRN, H.: Tolerance to contrast media in renal angiography. Acta radiol. 45 (1956), 141.

JOHNSTONE, C.: The relationship of blood uric acid content to the state of renal function in nephritis. J. Clin. Investigation 9 (1930—31), 55.

JOSSELSON, A. J. & KAPLAN, J. H.: Fatal reaction following aortography with Neo-Iopax. J. Urol. 72 (1954), 256.

KUNLIN, J., BITRY-BOELY, C. & VOLNIE, B.: Remarques sur l'aortographie. Rev. de chir. 69 (1950), 286.

LARSSON, H. & PALMLÖF, A.: Abdominal aortography. Acta radiol. 38 (1952), 111.

LODIN, H. & THORÉN, L.: Renal function following aortography carried out under ganglion block. Acta radiol. 43 (1955), 345.

McKay, E. M. & McKay, L. L.: The relationship between the blood urea concentration and the amount of functioning renal tissue. J. Clin. Investigation 4 (1927), 127 and 295.

Miller, G. M., Wylie, E. J. & Hinman Jr, F.: Renal complications from aortography. Surgery, 35 (1954), 885.

Ödman, P.: Percutaneous selective angiography of the main branches of the aorta. Acta radiol. 45 (1956), 1.

Olsson, O.: Renal angiography. Dixième congrès de la soc. internat. d'urol., Athènes, I (1955), 298.

Riches, E. W. & Griffiths, I. H.: Renal angiography. Dixième congrès de la soc. internat. d'urol., Athènes, I (1955), 271.

Seldinger, S. I.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 369.

Smith, H. W.: The Kidney. Oxford University Press, New York 1951.

Thomsen, G. & Hansen, T. A.: Abdominal aortografi. (Danish.) Ugesk. f. laeger 116 (1954), 369.

Trautner, K. & Pahle, H.: Renal arteriografi a.m. Pierce. (Danish.) Ugesk. f. laeger 116 (1954), 381.

Weyde, R.: quoted by Idbohrn.

FROM THE DEPARTMENT OF RADIATION BIOLOGY, SCHOOL OF MEDICINE AND DENTISTRY, UNIVERSITY OF ROCHESTER, ROCHESTER, N. Y., AND THE RADIOISOTOPE LABORATORY, U.S. NAVAL HOSPITAL, NATIONAL NAVAL MEDICAL CENTER, BETHESDA, MD., U.S.A.

THE EXCRETION OF THORIUM AND THORIUM DAUGHTERS AFTER THOROTRAST ADMINISTRATION

by

J. B. Hursh, L. T. Steadman, W. B. Looney and *M. Colodzin*

Thorotrast, a suspension of thorium dioxide, was widely used during the period 1930—1945 in diagnostic radiology primarily for visualization of the liver, spleen and cerebral arteries. Thereafter its use was curtailed, in part because of a low but significant incidence of injection site sequelae, and in part (9, 16) because of the recognition that thorium being the radioactive parent of a chain of radioactive daughters, might produce clinical changes or tumors. In support of the latter contention, it could be argued that the 15 gr thorium (plus its daughter products in equilibrium), contained in the 75 ml dose of Thorotrast used for hepatograms, was equivalent on an alpha particle energy basis to 2.1 μg radium. If account was taken of the respiratory loss of approximately 70 % of the radon formed from radium, and if it were assumed that none of the 54.5 second half-life thoron was lost from the body, the thorium dose became equivalent to 4.9 μg radium. Furthermore, roentgenograms taken many years after Thorotrast administration did not show any significant decrease in density over the liver and spleen. Since the total weight of the reticular endothelial system is very nearly equal to that of the skeleton (the site of deposition of radium) the average alpha energy/gram tissue/unit time would be in the approximate relation of

Submitted for publication 3 July 1956.

4.9 : 1 for the Thorotrast patient compared to a radium patient with 1 μg of fixed radium. Since skeletal roentgenographic changes and tumours have been found in patients with 0.5 μg of radium, it would appear that a *prima facie* case could be developed for the expectation that Thorotrast like radium might produce late clinical and neoplastic changes.

Interest has recently been revived in attempts to refine approximate dosage comparisons such as outlined above both with the purpose of establishing a probable prognosis for Thorotrast patients and with the more general objective of relating chronic low level radiation with biologic effects in human subjects. In order to refine the dose calculation it is necessary to obtain information on 1) the excretion of thorium as a function of time after administration; 2) the gross and the histologic tissue distribution of thorium; 3) the distribution and excretion of the thorium daughters formed in the body. It is in addition necessary to make some allowance for self-absorption of particle energy within the thorium dioxide particle aggregates which form in the reticulo-endothelial organs.

ROTBLAT and WARD (10) using the technique of autoradiography have explored the histologic distribution of thorium and its daughters enabling a calculation of the radiation dose to small tissue volumes. RUNDO (11) made calculations of the radiation dose on the same autopsy specimens from the chemical analyses. RUNDO's results were similar to those obtained by ROTBLAT and WARD. These authors in human autopsy material, and SHAEFER and GOLDEN (13) in tissue preparations from Thorotrast injected rabbits, have measured Thorotrast aggregates by microscopic inspection and assuming a simple geometric shape have calculated the effect of self-absorption in the latter.

STENSTRÖM (15) analyzed several samples of feces, urine and breath from two patients who had received 75 ml Thorotrast six and seven years previously. He measured alpha activity in ashed specimen. He found appreciable amounts of Ra^{224} in the feces and no measurable amounts in the urine. He was able to detect thoron in the breath. In addition he injected three rabbits with 2 ml Thorotrast intravenously and collected urine and feces and made tissue analyses of the sacrificed animals. As in human subjects, he found that Ra^{224} accounted for the major fraction if not all of the radioactivity of the excreta but that for rabbits the Ra^{224} content of the feces and of the urine were about the same. The tissue analyses showed highest alpha activity concentrations in the liver, spleen, and bone marrow. A later measurement of the tissue samples showed increase in the alpha activity indicating the presence of long-lived Ra^{226}, Th^{228} or Th^{232}. NORDENSTRÖM-BLOMQVIST (7) has measured the beta and gamma activity of urine and tissue samples after injection of Thorotrast into rabbits. Since the thickness of his Geiger

tube window did not permit direct measurement of alpha particles and since he measured sample ash without chemical separation it becomes difficult to place an exact interpretation on his results. He detects a short-lived daughter, presumably Ra^{224}, in the urine ash but also finds a longer-lived component contributing appreciable activity. In accordance with the findings of other investigators he finds the liver, spleen and marrow to contain the highest concentrations of radioactivity. Where comparison is justified the results of the experiments to be presented below agree for the most part with the findings of these two investigators.

In the present study the excretion of thorium and some of its daughters was determined after the administration of Thorotrast to two patients. A total collection of urine and feces was made from patient M. H. (A), a 58-year-old female, for the 17-day period from the administration of 72 ml Thorotrast to the time of death from carcinoma of the pancreas. Patient A. T. (B) who received 60 ml Thorotrast was a 34-year-old male who had osteogenic sarcoma. Daily collection of feces and urine was made for the first 8 days, following which spot 24 hour collections were carried out at increasing intervals up to 236 days from administration. Distribution studies of thorium were performed on autopsy tissue specimens from four Thorotrast patients. All Th^{232} analyses were made by a spectrochemical method which measured thorium as the element. The thorium daughters products, Ra^{224} and Ra^{228} were separated as radium by chemical procedure and determined by alpha and beta particle counting methods. Total body gamma ray activity and gamma ray activity over selected points of the body of patient A. T. were measured at various intervals over the 236-day period.

Thorium excretion

Spectrochemical analytical method. The spectrographic procedure followed very closely the method devised by STEADMAN (14) for uranium. Urine samples were wet ashed with nitric and perchloric acids. Feces were dry ashed in a muffle furnace at 500 to 600° C. Without further treatment suitable aliquots were added to the purest spectrographic carbons. Excitation of the sample aliquot by the d. c. carbon arc and the spectrum was obtained with a medium quartz spectrograph. Lines measured are thorium 2,837.3 Ångström units and platinum 2,650.8 as an internal standard. A tenfold gain in sensitivity is secured by using rubidium chloride as an enhancing agent. The smallest concentrations of thorium measurable are about 30 μg per liter of urine, and 10 μg per gram of feces ash. Smaller (to 1/3) amounts are detectable.

Table

Thorium determination

		Adrenal	Bone (cancellous)	Bone (compact)	Bone marrow	Heart	Intestine	Kidney
Ash wgt. sample (g)		0.019	0.097	0.020	0.075	0.003	0.007	0.022
Mg Th/g ash		55	0.32	0.03	38	2.9	15.9	30.0
Wgt. of sample (g)	Wet	5.3				4.8		6.3
	Ash	0.0142				0.0096		0.0162
Organ wet wgt. (g)						270		390
Mg Th/g wet		0.16				0.014		0.061
Mg Th/g ash		60				6.9		24
Wgt. of sample (g)	Wet	0.42				0.60		1.0
	Ash	0.0045				0.006		0.010
Mg Th/g wet		0.01				0.023		0.032
Mg Th/g ash		0.90				2.3		3.2
Ash Wgt. sample (g)			0.025	0.83	0.031	0.016	0.114	0.006
Mg Th/g ash			1.4	0.03	77	2.3	2.7	5.9

Results. The samples collected from patients M. H. (A) and A. T. (B) were analyzed according to the above procedure. The total excretion for patient A in 17 days was 0.7 per cent of the thorium injected. A total excretion for patient B, calculated by interpolating between spot checks, was 0.1 per cent dose for the first 108 days. With the exception of an initial unexplained high value for the urine of patient A on the first day (0.37 per cent) the fecal excretion rate was in general higher than urinary excretion (10 to 100 times in patient B). After 10 days patient A excreted thorium at the average rate of 0.0007 per cent dose per day. From the 24th to the 108th day the average daily excretion of patient B was no more than 0.0004 per cent dose per day. The data on both patients support the conclusion that the amount of thorium element excreted after Thorotrast administration is negligibly small.

Thorium tissue distribution

Analytical method. Tissue samples were digested in nitric acid when the thorium concentration was high and were dry ashed when it was very low. Subsequent treatment followed the spectroscopic method outlined above. The smallest concentrations of thorium measurable are 5 μg per 100 grams fresh tissue.

1

on tissue

Liver	Lung	Muscle	Pancreas	Spleen	Thyroid	
0.035	0.012	0.002	0.017	0.022	0.006	Patient M. H. 17-day interval between injection of 75 ml Thorotrast and death.
137	11.3	0.05	17	357	4.0	
7.2	15.2			10.3		Patient Y. C. (This patient had a primary hepatoma of the liver and abnormally high uptake probably occurred.) Interval of 49 days between injection of 60 ml Thorotrast and death.
0.0387	0.0402			0.0665		
4,600	1,260			650		
3.6	0.045			0.38		
670	17			59		
3.1	0.88		0.23	1.67		Patient L. W. 18-yr. interval between injection of 40 ml Thorotrast and death.
0.025	0.009		0.0023	0.016		
2.7	0.062		0.04	2.5		
330	6.1		4.0	264		
0.053	0.035	0.019		0.018	0.005	Patient A. D. 19-yr. interval between injection of 75 ml Thorotrast and death.
125	46	1.6		2,700	24	

Results. The results are presented in Table 1. Whole organ weights were available only on patient C. Y. The formalin preserved tissue specimens from patients C. Y. and L. W. were received at the analytical laboratory in excellent condition and the wet weights listed are those weights obtained after gentle blotting with filter paper. The tissue specimens from the other 2 patients did not permit valid wet weight measurement and the data are therefore presented on an ash weight basis. Tissue thorium analysis could serve three ends related to Thorotrast dosimetry. It could identify those tissues which, because of a high thorium content, should be regarded as particularly vulnerable. These data reaffirm the position taken on general grounds, *i. e.* that the reticulo-endothelial system, in particular the liver, spleen, and bone marrow, contains the major fraction of the thorium. The relatively high thorium concentration in the lung perhaps qualifies this organ as a member of the above group. A second use to which data of this sort might be put is to furnish a basis for calculation of the average dose rate to the vulnerable organs. The use of the data in Table 1 for this purpose has the following limitations. The fresh weight of the tissues of M. H. and A. D. must be inferred from ash weights. Secondly, since the whole organ was not analyzed, and since Thorotrast is known to be heterogeneously distributed in both a microscopic and macroscopic sense, the tabular values may differ somewhat from the true average. Thus, the thorium content of the liver,

patient Y. C., is the average of values for samples from the central and peripheral areas which differ by a factor of two.

A third use to which the data of Table 1 might be put is to guide the calculation of integral dose to take into account thorium excretion and tissue redistribution. On the basis of the 100-day excretion studies, we would expect no substantial diminution in thorium. The tissue analysis data do not provide evidence to the contrary. Comparison of the total body content in terms of percentage dose for the two short term versus the long term patients is at best an approximation since total organ weights are lacking in 3 of the 4 patients. For instance, the very high concentration of thorium in the spleen of patient A. D. is correlated with the observation at autopsy that the spleen had atrophied to a negligible size. Although an exact comparison is not feasible under the circumstances, it may be noted that the data showed no marked decrease in thorium concentration in the major organs of deposition as a function of time. Patients Y. C. and M. H. died 17 and 49 days after Thorotrast administration and the relative concentration in the liver was 670 and 137 respectively. Patient C. Y. had a large hepatoma of the liver so that a higher uptake of the Thorotrast may have occurred as a result of the tumor. Patients A. D. and L. W. died 19 and 18 years after Thorotrast administration and the relative concentration in the liver was 125 and 620, respectively. (Liver concentration for patient L. W. has been normalized to 75 ml initial dose.)

Excretion of Ra^{224}

Characterization of injected Thorotrast. In order to interpret the results on Ra^{224} analysis of excreta, it is necessary to know the daughter product concentration in the injected Thorotrast. By examination of the decay chart presented in Diagram 1, it is apparent that the 3.64 day half-life Ra^{224} and its daughters as well must be in radioactive equilibrium with Th^{228}, the 1.9 year half-life immediate parent. The measurement of Ra^{224} in the injected material therefore serves to characterize the activity concentration of these members of the chain. The analysis was accomplished by separating the radium element from a measured volume of Thorotrast suspension by means of the method of AMES et coll. (1) as modified by RUSSELL et coll. (12). According to this method radium-barium carrier sulphate was deposited in a thin layer on a circular glass disc. The dried deposit was counted in a 2π proportional alpha counter. Since the aliquot of Thorotrast contained a known weight of Th^{232} and therefore a known disintegration rate (due to Th^{232}), the Ra^{224} measurement enabled the calculation of the Ra^{224} : Th^{232} activity concentration ratio which was in our material equal to 40 %. Beta counting of

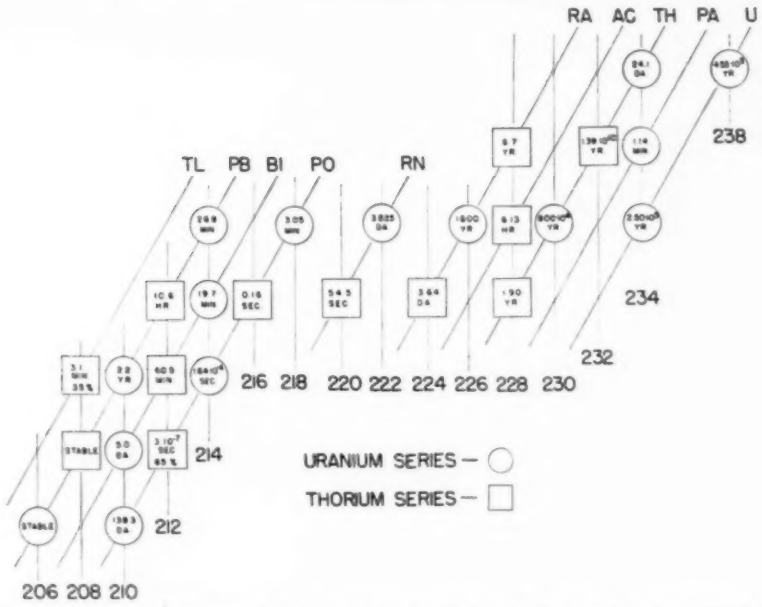


Diagram 1. The decay scheme for the uranium and the thorium series. In general decay progresses from the upper right area to the lower left area of the chart. Progression horizontally to the left occurs when an alpha particle is emitted. Progression downwards connotes a beta particle emission.

the same plaque after 30 days to allow decay of Ra^{224} and its daughters establishes the activity ratio of Ra^{228} : Th^{232} found in this case to be approximately 10 %.

The relative amounts of Ra^{224} and Ra^{228} are not compatible with any known age of an initially pure thorium preparation. This leads to the conclusion that (as found by RUNDO (11) for Thorotrast suspensions) the radium daughters may adsorb on the sides of the glass thorium vial.

This has been verified by us by direct experiment. However, consistent results on different aliquots of the thorotrast batch injected make it probable that the adsorbed radium is constant and therefore that in all likelihood the daughter product content of the injected solution is as measured. Subsequent calculations of the percentage body content depend on this assumption.

Analytical method for Ra^{224} in excreta. The urine samples were wet ashed with concentrated nitric and perchloric acid. Feces were dry ashed in a muffle furnace at 600° C. The dissolved samples were treated according to the chemical method referred to above for radium separation and sample preparation. The data were corrected for counter geometry and for decay to time of voiding.

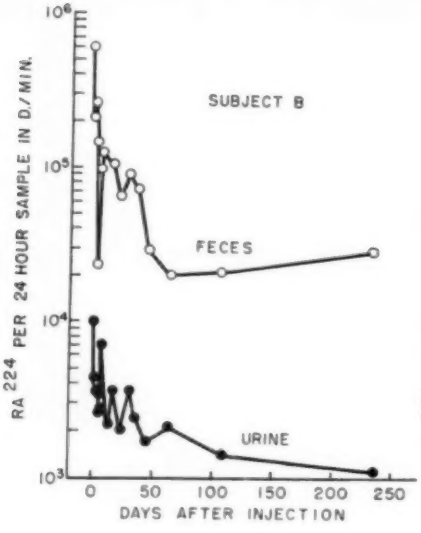


Diagram 2

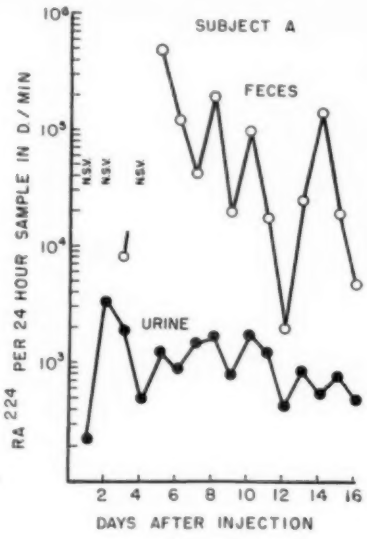


Diagram 3

Diagram 2. Urinary and fecal excretion of Ra^{224} from patient A. T. (B) as a function of time after Thorotrast injection.

Diagram 3. Urinary and fecal excretion of Ra^{224} from subject M. H. (A) as a function of time after Thorotrast injection. The notation N. S. V. indicates that no sample was voided on that day.

Experimental results. Diagrams 2 and 3 present the data obtained on patients M. H. (A) and A. T. (B). It is seen that in human subjects the major route of excretion of Ra^{224} is by way of the feces, the urinary excretion rate being more than 10 times lower. In both the urine and the feces there occurs a rapid initial decrease in the daily excretory rate, followed by a slower decline and an approximately constant rate at 50 days and thereafter. Diagram 4 plots the radium^{224} body content for patient B, taking excretion data from the curve connecting the experimental points shown in Diagram 2, and making appropriate allowance for the constant formation of new atoms of Ra^{224} from Th^{228}. The plot is not shown beyond 70 days since the body content remains stable at about 88 % up to the limits of measurement at 236 days. The open circles joined by the dotted line on Diagram 4 represent whole body gamma counts made on this patient with a crystal scintillation counter. The measurements probably reflect changes in the Pb^{212} body content of the patient.

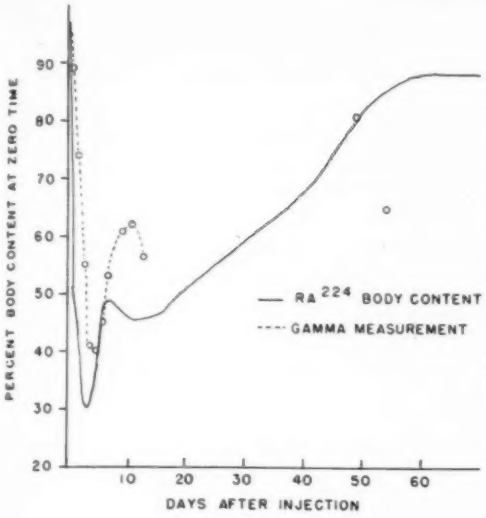


Diagram 4

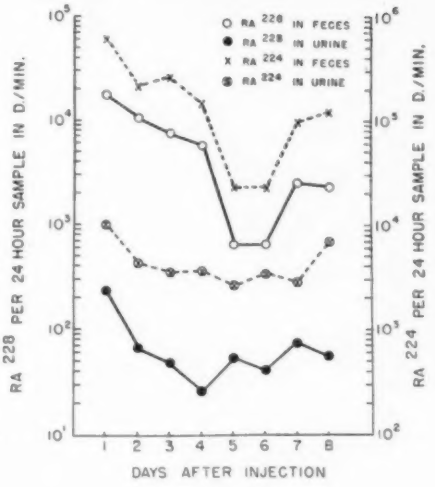


Diagram 5

Diagram 4. Ra^{224} body content of patient A. T. (B) as a function of time after Thorotrast injection. The dotted line represents total body gamma ray measurements made with crystal scintillation counter technique.

Diagram 5. Excretion of Ra^{228} after intravenous injection of 60 ml Thorotrast to patient B. For comparison excretion of Ra^{224} is shown for the same period.

Ra^{228} excretion

Analytical method. The radium plus barium carrier sulfate deposits on the glass counting discs prepared for Ra^{224} assay were allowed to stand for 30 days or more and were then counted in a 2 π proportional beta counter for Ra^{228}. An alternative determination used as check involved the preparation of radium-barium deposits from the original excreta samples at 90, 180 and 230 days after voiding. The virtual absence (a reasonable inference from the Th^{232} data supported by the results taken at different times after voiding) of Th^{228} in the samples when voided permitted the calculation of the Ra^{228} content from alpha measurements of the Ra^{224} in equilibrium with the Th^{228} produced from Ra^{228} after voiding of the excreta samples. Results by the two methods were in agreement.

Experimental results. Since Ra^{224} and Ra^{228} are isotopes and since measurement of Thorotrast from the same batch as that injected gave activities in the ratio of 4 : 1 it might be expected that in the early

period after injection, the excretory processes of the body would not differentiate between them and that amounts in the above activity ratio would be voided. (At later stages, if a large fraction of the body content were excreted, the differences in regeneration rate (*i. e.* 3.64 day as compared to 6.7 year half-lives) would result in inequalities in body content and therefore in excretion.) Diagram 5 shows that this expectation is far from being realized. The excretion of Ra^{228} is given and for comparison the ratios of the activities Ra^{228}: Ra^{224} are listed for the first 8 days on Subject B. Results on later samples showed approximately the same relationship but the Ra^{228} data became less exact as the measured activity decreased. It will be noted that the ratio varies unsystematically between about 1 and 5 %. This unexpected result led to a dialysis experiment on Thorotrast from the same batch as that injected. A dialysis bag containing 1 ml of Thorotrast diluted to 8 ml volume with distilled water was slowly rotated in a beaker containing 500 ml of acidified (pH 5) distilled water. After 22 hours it was found by analysis of the dialysate that 98 % of the Ra^{224} had passed through the membrane whereas only 30 % of the Ra^{228} appeared in the outer solution. The experiment was repeated with substantially the same result.

These data suggest that the unexpectedly low ratio of Ra^{228} to Ra^{224} excreted was caused by the circumstance that a major fraction of the Ra^{228} existed in a non-dialyzable, non-ionic form presumably because of entrapment in the thorium dioxide particle. This leaves unsolved the underlying question as to why a large fraction of the Ra^{228} should be trapped and Ra^{224} free to diffuse in the Thorotrast suspension injected. An adequate explanation must take into account several complex physical and chemical situations such as the experimental finding that Ra^{228} adsorbs on the glass vials containing Thorotrast to a greater extent than Th^{228} (in equilibrium with Ra^{224} in solutions tested), that no Th^{228} is found in the dialysate, and that Ra^{224} will have experienced four disintegration events as compared to two disintegration events for Ra^{228}. Such an explanation has not been worked out and is in any event beyond the scope of this report.

External gamma ray measurements. A non-collimated sodium iodide scintillation counter with a pulse height discriminator was used for the gamma measurements. A modification of the method developed by R. D. EVANS (4) similar to that recently described by MARINELLI et coll. (6) was employed.

The gamma content of the thorium in 75 ml of Thorotrast would be equivalent to about 1.4 micrograms of radium provided these substances were in radioactive equilibrium with all their daughter products. Recently extracted thorium would take about 30 years to achieve equilibrium with its daughters, so the administered Thorotrast is far from equilib-

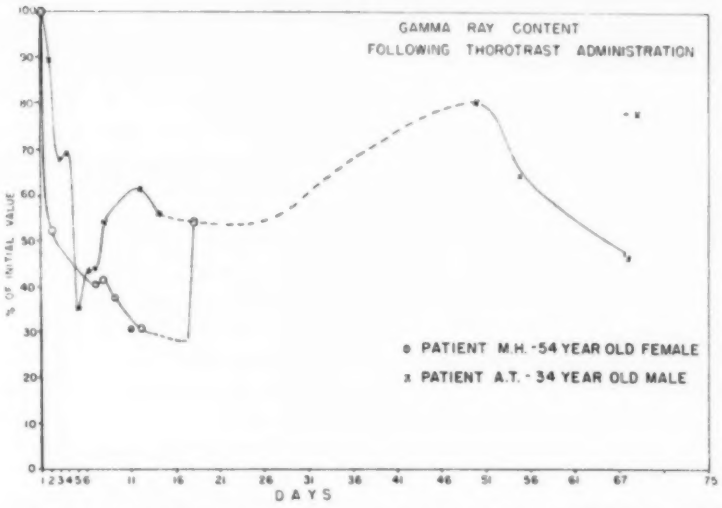

GAMMA RAY CONTENT
FOLLOWING THOROTRAST ADMINISTRATION
% OF INITIAL VALUE
DAYS
o PATIENT M.H. - 54 YEAR OLD FEMALE
x PATIENT A.T. - 34 YEAR OLD MALE

Diagram 6. Total body gamma ray measurements on patients M. H. (A) and A. T. (B).

rium. In addition, some radium isotope daughters injected with Thorotrast are rapidly eliminated.

The background count for these measurements was in the neighborhood of 500 cm. Counting times were 45 minutes per position of the patient. Net counting rates from the patient at 1 meter ranged from about 10 % to 50 % of the background. Thus the results of these measurements are subject to quite a large experimental error.

The two patients who were recently injected, received 75 ml and 60 ml of Thorotrast. Estimates of the total body gamma activity were made throughout the 17-day period on patient M. H. (A), as well as 7 hours after death. Patient A. T. (B) was counted daily for the first 8 days and again at various intervals afterwards.

A plot of these measurements with the ordinate expressed as a percentage of the initial values appears in Diagram 6. Curves of both patients show a steep initial drop. The data from the female patient M. H. (A) plots a rather smooth curve and shows a rise of approximately 24 % in 7 hours following death. The curve of patient A. T. (B) also shows the initial steep drop of gamma activity. Later values, however, show a rise in the gamma activity and variations between values from 35 % to 80 % at different times up to 67 days. A measurement of 56 % obtained on the 240th day is omitted on the graph.

In addition, to the whole body measurements, gamma ray activity over different parts of the body was recorded from patient A. T. (B).

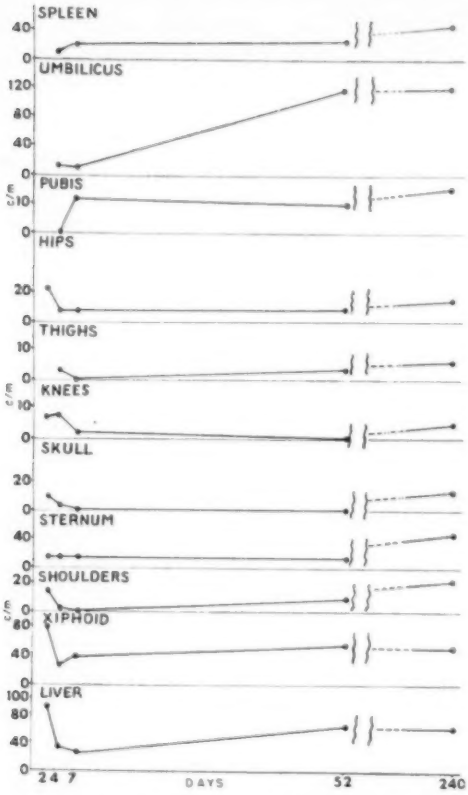


Diagram 7. Gamma ray measurements at selected points on patient A. T. (B).

The scintillation counter with added lead shielding to achieve collimation, was used. Since we were looking at only a small amount of tissue, net counting rates were quite low in most of these measurements.

If the radium and later daughter products are moving about the body, or if the total body content is altering, change in the gamma activity over a particular part of the body is to be expected. Distribution gamma counts were performed on patient A. T. (B) at 2, 4, 7, 52 and 240 days following injection. The positions were reproduced on different days by using anatomic landmarks. The results are recorded for the positions over the skull, sternum, shoulders, xiphoid, liver, spleen, umbilicus, pubis, hips, thighs, and knees (Diagram 7).

Fewer than 25 counts per minute (c/m) were obtained over the knees, thighs, hips, pubis or skull at any one time, but all of these show an initial drop and then a later rise. The liver shows an initial drop from 90 c/m the 2nd day to 27 c/m on the 7th day. It rises to 64 c/m on the 52nd day and was about the same on the 240th day. Over the umbilicus initial low values rose to 120 c/m on the 52nd day and the same on the 240th day. The spleen showed initial low values rising to 45 c/m on the 240th day.

Discussion

Table 2 lists the implications of the data pertinent to calculation of dosage from Thorotrast. The table is in part based on the assumption that the steady state, which appears to be established at approximately

Table 2

Implications of the data as applied to calculation of dosage from Thorotrast

	Th^{232}	Ra^{228}	Th^{228}	Ra^{224}
State in injection material	Dioxide, Insoluble particle	30 % dialyzable	Less than 0.1 % dialyzable	98 % dialyzable
% body content excreted per day calculated for 60 days, *i. e.* after 'steady state' is established.	$> 2.5 \times 10^{-4}$ $< 4.5 \times 10^{-4}$	(0.026) Values which are less well established in the authors' opinion are enclosed in parenthesis.	(as Th^{232}, *i. e.* negligible)	2.6
Biological half-life	< 760 yr. > 420 yr.	—	—	—
Body content in % Th^{232} activity	100		Decreases from 40 % to approximately 30 % at 3 yr. then increases to 51 % at 20 years. Average = 39 %. (Stipulated for the particular Thorotrast solution injected in these experiments.)	0.88 times Th^{228} activity

60 days after injection in these experiments, is associated with excretion rates (percentage body content per day) which are essentially unchanged thereafter.

The specific values for the daughters in terms of body content in per cent Th^{232} activity depend on the time after injection and on the parent-daughter activity ratios in the injected Thorotrast material. For the Thorotrast used in the present experiment (as defined by the analysis of Thorotrast from the same batch as that injected) it is estimated that Th^{228} would vary as indicated in the table and that Ra^{224} and its daughters would be retained at 88 % of the Th^{228} activity. If the estimate of 0.026 % body content excreted per day is valid for Ra^{228}, the body Ra^{228} content would increase over the years, with an effective half-time of 3.5 years, to a steady state value equal to 52 % of the Th^{232} activity. The choice of the value for excretion rate is an arbitrary one made to agree with the following experimental measurements. Alpha counts were performed on Ra-Ba preparations from the autopsy tissues of patient A. D. who carried Thorotrast for 19 years before death. Since several months intervened between the patient's death and the measurements referred to, the Ra^{224} count is a measure of the Th^{228} activity. Likewise, since Th^{228} is excreted to a negligible extent, radioactive equilibrium

is to be expected between Th^{228} and Ra^{226}. (It is assumed throughout this argument that the 6.13 hour half-life actinium is not excreted or translocated.) Measurements of some ten different tissues gave inferred concentrations of Ra^{228} which for the most part fell in the range of 40 to 65 % of the Th^{232} activity calculated for that tissue from spectrochemical analysis. Since the comparative measurements were not made on the identical samples, the heterogeneous distribution of Thorotrast adequately accounts for the range of values found.

The different rates for excretion of Ra^{228} and Ra^{224} was at first difficult to interpret. In retrospect it seems as if something of the sort should have been anticipated. The finding (12) that daughter products existed in substantial fractions of the Th^{232} activity as measured in autoradiographs from patients carrying Thorotrast for 10 to 20 years should have suggested that the 6.7 year Ra^{228} had been 'conserved' by the body in a very special way. If we were to entertain the hypothesis that Ra^{228} was formed in the body, diffused into the circulation and deposited in the skeleton in the same way as injected Ra^{226} might do, we would immediately have at our disposal a considerable body of information (8) collected on Ra^{226} which would specify expected excretion rates and skeletal retention. Using such data it would be predicted that less than 1 % of the Ra^{228} formed would be retained in the body. Were this the case, the radioactive injury potentialities of Thorotrast could be dismissed without further consideration. The average dose rate (75 ml Thorotrast) on a basis of alpha energy absorbed per gram would become approximately 2/3 of that associated with injury (0.5 μc Ra^{226}) and this could be further reduced by allowing for self-absorption in Thorotrast aggregates.

Unfortunately, it is abundantly clear that the Ra^{228} which is injected as a component of the Thorotrast or formed in the body from Th^{232}, does not behave as a freely diffusable ion. It seems likely that it is entrapped in the thorium dioxide particles, and perhaps further immobilized by the formation of the particles into aggregates within the body. Since these aggregates are deposited in the organs of the reticuloendothelial system, it is probable that this site contains over 90 % of the Ra^{228} body content.

It might be expected that Ra^{224} excretion would be similar to Ra^{226} excretion. If this comparison is made it is found that for the first few days after Thorotrast injection the Ra^{224} acted like Ra^{226}, *i. e.*, as if it occurred in a freely diffusable form. At later times the daily excretion dropped and in terms of the Ra^{224} formed per day it would appear as though only one fifth or less participated in the body excretory processes as diffusible freshly injected radium. The experimental data provide no direct evidence as to the cause of this change. It is, however, known

that the injected particles form aggregates which increase in size in the body and this process may prevent a large fraction of the formed radium from reaching the circulation before decay. On the basis of this interpretation, the principle site of Ra^{224} deposition and decay would be the reticulo-endothelial system.

The initial decrease in total body gamma ray activity corresponds to the early radium isotope excretion found in two patients immediately after Thorotrast administration. The rise in gamma ray activity with variation between 35 % to 80 % up to 67 days and a measurement of 56 % of the initial activity at 240 days corresponds to the time of the establishment of a relatively steady state of excretion at about 60 days after administration.

The gamma ray activity in patient M. H. 7 hours after death increased approximately 24 %. This is considerably higher than we would expect from the radium isotope excretion measurements. From this data we inferred the possibility that a source of the gamma ray emitters toward the end of the chain might be excreted more rapidly than others. The data is compatible with a more rapid excretion of the Pb^{212} isotope with a 10.6 hour half-life. The results of the measurements on patient A. T., however, do not indicate a differential excretion of Pb^{212}. Also we found little activity over the bladder of patient A. T. before voiding. Experiments in dogs following the injection of Th^{228} by VAN DILLA (17) showed a rate of build up of gamma ray activity after death which was incompatible with an increased excretion of the Pb^{212} during life.

The early decrease in gamma ray activity found over most of the points counted in the distribution study corresponds to the period of rapid excretion of the radium isotopes immediately following Thorotrast administration. (Diagram 4.) The rise in activity over most of the points after 50 days is comparable to the results of the total gamma ray measurement.

Despite the speculative nature of some features of the argument presented, it seems worthwhile to make an approximate calculation of average dosage to the organs of the body having the highest thorium concentration based on what appear to be reasonable inferences. The results of such calculations are entered in Table 3. Table 1 was used as a guide in choice of tissue thorium concentrations, but the precise values are arbitrary ones which when assigned to organ weights of the 'standard man' (3) approximately account for the 15 grams of thorium in the 75 ml of Thorotrast used for hepatograms. Other pertinent assumptions are listed in the table. The value of 50 % self-absorption in the aggregates is an arbitrary choice which lies within the range of the values calculated by ROTBLAT and WARD (10). The average dose rate of 0.3 reps per day to the liver and spleen of the Thorotrast patients may be compared

Table 3

Calculation of average dose from Thorotrast

Vulnerable organ	mg Th^{232} / g wet wgt.	Av. dose/day (reps)	Definitions and assumptions
Liver or spleen	6.5	0.3	1 rep = 95 ergs/g tissue. No excretion of Th^{232} or Th^{228}
Bone marrow	0.6	0.03	Average (0—20 yr) Th^{228} content of R. E. organs = 0.39 times Th^{232} content in activity units.
Lung	0.2	0.01	Average Ra^{224} (+ daughters) content of R. E. organs = 0.80 × 0.39 times Th^{232} content. Average self-absorption of aggregates = 50 %.

with the calculated average dose rate to the bone of human subjects having 1 μg of Ra^{226}. Assuming 1) that 70 % (8) of the radon is lost in the expired breath, and 2) that the skeleton weight (3) is 7,000 grams, an average dose rate of 0.1 rep per day is calculated.

Radium doses ten times higher (2) may be delivered to small hot spots in the bone. Likewise autoradiographic studies of Thorotrast patient tissues show alpha particle track concentrations in small volumes approximately 10 times higher than the average track concentration. This heterogeneity of thorotrast particle distribution may account for the difference between the calculated 0.3 reps per day average dose to liver (75 ml Thorotrast) and the ROTBLAT and WARD (10) determination of 1.16 reps per day (22 ml Thorotrast) to small volumes of the liver based on autoradiographic analysis.

Therefore, the estimated dose rate to the Thorotrast patient liver is 6 times the dose rate to the bone from 0.5 μg radium. In spite of the higher dose rate, there have been relatively few clinical findings which could be attributed to Thorotrast administration. The explanation may depend upon two important differences between the patients who received radium and the patients who received thorium.

First, the average time of retention is longer for the radium patients than for the Thorotrast patients. The average latent period for skeletal tumor formation was about 25 years. It may be as JOHANSEN (5) suggested that an insufficient time has elapsed for the development of clinical changes to occur in the Thorotrast patients. Recent results indicate that this assumption is valid in regard to tumor formation.

The second important difference is the difference in distribution of radium and thorium. Since radium is primarily deposited in the skeleton the effects have been primarily skeletal destruction and tumor formation. Our lack of information about the process of cancer induction prevents us from carrying the argument beyond indicating that the liver, spleen, bone marrow and lungs may be more resistant to cancer induction by chronic radiation than bone. The lack of other clinical changes may be

the result of greater regenerative powers of these organs or less sensitive clinical means for detecting damage.

A portion of this work was performed under contract with the United States Atomic Energy Commission at The University of Rochester Atomic Energy Project, Rochester, N. Y. Part of the information in this paper was incorporated in a report (8/P/479) "A Summary of Radium and Thorium Excretion in Humans", by W. B. Looney, J. B. Hursh, V. E. Archer, L. T. Steadman and M. Colodzin, for the First International Conference on the Peacetime Uses of Atomic Energy, Geneva, 8—20 August 1955.

SUMMARY

The thorium and thorium daughter product content of excreta were analyzed for the early period after administration of 75 and 60 ml of Thorotrast respectively to two human subjects. Autopsy tissues from four Thorotrast patients were analyzed for thorium. It was found that less than 1 % of the administered thorium was excreted in the early period and a biologic half-life of more than 400 years is calculated. Ra^{228} excretion is modified by the physical nature of the injected material and it is estimated that 0.026 % of the body content is excreted per day in the 'steady state'. Ra^{224} excretion is at the rate of 2.6 % of the body content per day after a state of transient equilibrium has been established. The total body gamma ray measurements and gamma ray distribution studies gave results which were similar to the excretion results of the radium isotopes. Dosage calculations are made for the organs of maximum thorium deposition, *i. e.*, the liver, spleen, bone marrow, and lung.

ZUSAMMENFASSUNG

Der Gehalt der Exkreten von Thorium und dessen Tochtersubstanzen wurde für die frühe Periode nach Administrierung von 75 bezw. 60 ml Thorotrast bei 2 Versuchspersonen analysiert. Sektionsgewebe von 4 Thorotrastpatienten wurde auf Thorium geprüft. Man fand, dass weniger als 1 % der administrierten Thoriummenge in der frühen Periode ausgeschieden wurde und eine biologische Halbwertzeit von mehr als 400 Jahren wird kalkuliert. Die Ausscheidung des Ra^{228} wird durch die physikalischen Eigenschaften des injizierten Materiales modifiziert und es wird geschätzt, das 0.026 % der im Körper befindlichen Menge im 'stabilen Stadium' ausgeschieden wird. Die Ausscheidung des Ra^{224} liegt bei 2.6 % des Körpergehaltes per Tag, nachdem ein Zustand vorübergehenden Gleichgewichtes erreicht worden ist. Die Gammastrahlenmessungen vom ganzen Körper und die Studien über die Verteilung der Gammastrahlen ergaben Resultate, die denen bei der Ausscheidung von Radiumisotopen ähnlich waren. Dosisberechnungen für die Organe mit maximaler Thoriumablagerung wie Leber, Milz, Knochenmark und Lungen wurden ausgeführt.

RÉSUMÉ

Les auteurs ont mesuré la teneur des excreta en thorium et en produits de désintégration du thorium au cours de la période qui a suivi immédiatement l'administration à deux sujets humains de respectivement 75 et 60 ml de Thorotrast. Ils ont dosé le thorium dans les tissus prélevés à l'autopsie de quatre malades ayant reçu du Thorotrast. Ils ont constaté que moins de 1 % du thorium administré fut excrété pendant la période initiale et ont calculé que sa demi-vie biologique est supérieure à 400 ans.

L'excrétion du Ra^{228} dépend de la nature physique du produit injecté et les auteurs estiment que 0.026 % de la quantité contenue dans le corps est excrété par jour pendant 'l'état d'équilibre'. L'excrétion du Ra^{224} se fait à raison de 2.6 % par jour du contenu du corps après l'établissement d'un état d'équilibre transitoire. Les mesures de rayonnement gamma de tout le corps et les études de répartition du rayonnement gamma ont donné des résultats semblables à ceux de l'étude de l'excrétion des isotopes du radium. Les auteurs ont fait des calculs de dose pour les organes de fixation maximum du thorium, à savoir le foie, la rate, la moëlle osseuse et les poumons.

REFERENCES

1. Ames, D. P., Sedlet, J., Anderson, A. H. and Kohman, T. P.: Rapid radiometric assay for radium and application to uranium ore process solution. Paper 22. 70. The transuranium elements. Natl. Nuclear Energy Ser. Div. IV, Vol. 14B. McGraw-Hill Book Co., New York 1949.
2. Aub, J. C., Evans, R. D., Hempelmann, L. H. and Martland, H. S.: The effects of internally deposited radioactive materials in man. Medicine 31 (1952), 221.
3. Bureau of Standards Handbook 47. Recommendations of the International Commission on Radiological Protection and of the International Commission on Radiological Units, 1950. U. S. Department of Commerce.
4. Evans, R. D.: Radium Poisoning II Quantitative determination of radium content and radium elimination rate of living persons. Am. J. Roentgenol. 37 (1937), 368.
5. Johansen, C.: Histological changes in man and rabbits after parental thorium administration. Radiobiology Symposium 1954, p. 358. Academic Press, New York 1955.
6. Marinelli, L. D., Miller, C. E., Gustafson, P. F. and Rowland, R. E.: The quantitative determination of gamma ray emitting elements in living persons. Am. J. Roentgenol. 73 (1955), 661.
7. Nordenström-Blomqvist, B.: An attempt of excreting injected Thorotrast in rabbits by 2,3-dimercaptopropanol (BAL). Acta radiol. 34 (1950), 533.
8. Norris, W. P., Speckman, T. W. and Gustafson, P. F.: Studies of the metabolism of radium in man. Am. J. Roentgenol. 73 (1955), 785.
9. Reeves, D. L. and Stuck, R. M.: Clinical and experimental results with Thorotrast. Medicine 17 (1938), 37.
10. Rotblat, J. and Ward, G. B.: Tissue dosage from Thorotrast in the body. Nature 72 (1953), 769.
11. Rundo, J.: Considerations of the dosage limits from Thorotrast. Brit. J. Radiol. 28 (1955), 615.
12. Russell, E. R., Lesko, R. C. and Schubert, J.: Determining radium in exposed humans. Nucleonics 1950: 7, p. 60.
13. Shaefer, H. J. and Golden, A.: The effectiveness of colloidal thorium dioxide as an internal alpha emitter: a combined morphologic and radioautographic study. Yale J. Biol. & Med. 27 (1955), 432.
14. Steadman, L. T.: A spectrographic method for the determination of uranium. Pharmacology and toxicology of uranium compounds. Nat. Nuclear Energy Ser., Div. VI, Vol. 1. McGraw-Hill Book Co., New York 1953.
15. Stenström, W.: Elimination of radioactive elements by patients and rabbits after injection of Thorotrast. Radiology 37 (1941), 698.
16. Taft, R. B.: The dangers of Thorotrast. Radiology 29 (1937), 530.
17. Van Dilla: Personal communication.

BOOK REVIEWS

GRENZEN DES NORMALEN UND ANFÄNGE DES PATHOLOGISCHEN IM RÖNTGENBILDE DES SKELETTES. Von A. Köhler †, und E. A. Zimmer. 10. Aufl. 704 S., 1,282 Abb. Georg Thieme Verlag, Stuttgart 1956. DM 94.—.

This is the second time that Köhler's classical reference work appears with E. A. ZIMMER as the editor. At least 30 pages of subject matter has been added to the text in the 10th edition of this excellent standard work. Most of the small faults in the ninth edition have been corrected, and recent experiences are reported. The new issue may therefore safely be called a markedly improved edition. The publishers and the editor may be congratulated upon the good result of their endeavour. The book will surely be appreciated by roentgenologists all over the world; it appears in the German as well as in the English and French languages. It is therefore, perhaps, no exaggeration to say that without this encyclopedia it would not be easy to pursue any activities in the field of skeletal diagnostics.

Only in a few instances, referring to minor details, might the reviewer feel inclined to express a divergent opinion, as when it is stated, for example, that arthrosis of the tempero-mandibular joints may lead to a low bite. The opposite seems to be more correct, *i. e.* that occlusal imbalance with low bite may lead to arthrosis. Small irrelevances like this are not of a kind, however, to reduce the value of this excellent handbook in which the practitioner can really find what he needs to know. The scopes of the different sections are well-balanced, and the roentgenologist engaged in scientific research will gain his first starting point in his search for literature in the large field of skeletal diagnostics.

S. Ribbing.

THE SPINE (Anatomic-radiographic studies. Development and the cervical region). By Leo A. Hadley. 156 pages, 121 figures. Charles C. Thomas, Springfield, Ill., 1956. $ 6.50.

By way of introduction, a recapitulation is given of the development of the vertebrae in the prenatal and postnatal stages. The section which follows consists of an account of disturbed development of various kinds, illustrated by cases from the author's own material. Ununited vertebral ring apophysis is mentioned although it would seem to have been proved (NIEDNER 1932, inter alios) that this condition is due to detachment of the margin of the vertebral body occurring at a later stage.

The author devotes much attention to describing anomalies in the occipito-cervical region and the cervical spine generally. Clinical cases as well as descriptions of anatomic preparations are included. The cervical spine has been examined in extreme ante- and retro-flexion. A gliding movement between the vertebral bodies is a normal condition in this region and does not constitute evidence of disc degeneration as it does in the lumbar spine. The somewhat capricious relationship between nerve root signs and encroachment of the foramen is stressed.

The book is richly illustrated and the comparisons made between roentgenologic observations in living subjects and anatomic preparations are both interesting and valuable.

Folke Knutsson.

STRAHLENDOSIS UND STRAHLENWIRKUNG. TAFELN UND ERLÄUTERUNGEN, UNTERLAGEN FÜR DEN STRAHLENSCHUTZ. 2. Aufl. Von B. RAJEWSKY unter Mitarbeit von K. AURAND, O. HUG, H. MERGLER, H. MUTH, H. PAULY, A. SCHRAUB, E. SIX, I. WOLF. 486 S. Georg Thieme, Stuttgart 1956. DM. 36.—.

The first edition of this book (1954) contained a wealth of material on various biologic reactions to radiations, and an extensive bibliography primarily collected with reference to their importance in radiation protection. It was much appreciated and rapidly sold out. The second revised and enlarged edition which has now appeared thus meets a much-felt need. The authors are to be congratulated for having mastered so well the task of collecting all this information. The magnitude of their problem is reflected by the fact that the reference list has grown from about 3,100 to 7,000 publications in the two years between the editions. The addition of a subject index to the bibliography is thus a useful innovation in the second edition.

The text part of the book gives a short but good general introduction on biologic effects of radiation and on dosimetry, followed by explanations of the tables. It is easily read, except perhaps the section upon the calculation of the risks from radioisotopes in the body, which is necessarily somewhat mathematical. The text is followed by a number of tables and diagrams summarizing the results of radiobiology of importance in radiation protection, the physical and metabolic properties of all important isotopes, maximum permissible concentrations in air and water, the International Recommendations, permissible doses under emergency conditions, and atomic bomb effects.

The book can thus be strongly recommended to all interested in radiation protection, a subject of a large and rapidly increasing public interest.

Sven Benner.

CLINICAL ROENTGENOLOGY. Volume Four. The digestive tract and gallbladder. The liver and pancreas. The excretory tract. By A. DE LORIMIER, H. MOEHRING and J. HANNAN, 764 pp. and 1,112 illustrations. Charles C. Thomas, Springfield, Ill, 1956. $ 24.50.

This book which, according to the authors, is written for practical clinical use, is evidently more a guide for the student and the clinician than a textbook for the specialist, and seen from this viewpoint is difficult to criticize. Some chapters are too short and are of limited value, but on the other hand there are many which cover the subjects extensively. The main points are usually stressed and characteristic findings shown; short references are included. The digestive tract is most adequately presented and many remarkable clinically corroborated cases are described. The authors are evidently more experienced in routine contrast medium examinations than in the investigation of acute abdominal conditions, which latter are treated in a somewhat cursory manner.

The gallbladder and biliary ducts are well described, although this cannot be said for the important examination by means of the intravenous injection of contrast medium.

The urinary tract section includes some interesting cases although too many of these have been examined by retrograde pyelography instead of intravenous urography which, in the reviewer's opinion, is to be preferred. Aortography has been performed by the original translumbar route and not by percutaneous catheter replacement which is much safer. Lieno-portal venography is not described.

In the diagnosis and treatment of renal cysts, puncture and the injection of contrast medium are not mentioned.

The chapter on gynaecology and obstetrics may be of help for those searching for guidance in various roentgen methods in this field.

It certainly takes a long time to get such a volume ready for printing, and in medicine today we cannot always expect such an expensive textbook to be quite up to date when it is published. This work is, however, a valuable contribution to diagnostic radiology and should, no doubt, be valuable in many departments.

J. Frimann-Dahl.

ZWERCHFELLPATHOLOGIE IM RÖNTGENBILD. Von R. Haubrich. 303 Seiten, 210 Abb. Springer Verlag, Berlin 1957. DM 98.40.

This book covers an investigation of normal function of the diaphragm and the changes which occur in various diseases of the thorax and abdomen. A protest may be raised at the conception of a book upon diseases based upon a particular anatomic landmark particularly if most of the details have already been covered in the roentgenologic literature. On the other hand such complete, or almost complete, treatment of a structure is, it must be admitted, valuable. The author who has evidently devoted his attention to the subject with zest and the greatest care, has unfortunately produced a book which is a tiring one to read, filled as it is with references many of which appear to be redundant. The deletion of some of these would certainly make the text more readable and interesting.

The author has used kymography quite extensively for examination of the diaphragmatic movements. This method may certainly be helpful for the registration of the excursions, but in the reviewer's opinion contains many pitfalls which are not sufficiently stressed. Referred pulsations and movements may, for instance, be wrongly interpreted as movements of the diaphragm, and the serrated contour is at times really impossible to estimate. The simple procedure of making two exposures on the same film, in expiration and inspiration, as advised by the reviewer in 1935 seems to be preferable, at least when combined with fluoroscopy. This method, however, is neither mentioned nor used by the author. Apart from the more instructive representations obtained by the double-exposure, the films are more easily interpreted and not so difficult to study as the innumerable peaks in the kymogram.

The chapter upon the pneumoperitoneum offers nothing new, and the findings in diaphragmatic lesions in acute abdominal diseases — of very considerable importance — are only briefly mentioned. Changes which occur in diseases of the lungs and heart are described with precision and are well presented. It would appear that traumatic lesions are the most familiar to the author, and it is stressed that the roentgen examination is the only means of diagnosis.

Various types of diaphragmatic herniation are well covered and are well illustrated. Paralysis of the diaphragm (or hemidiaphragm) as well as tumours of the structure have been carefully studied.

The book can be recommended for a place upon the bookshelf where it will be of considerable value when the need arises.

J. Frimann-Dahl.

LA POLYARTHRITE. CHRONIQUE EVOLUTIVE. Par L. Isemein et A.-M. Fournier. 315 pages et 192 figures. Masson et Cie., Paris 1956. 3,200 fr.

A section of this book, comprising 100 pages and 130 illustrations, deals in a most exhaustive manner with the roentgenologic changes occurring in polyarthritis. Thus, the authors present detailed accounts of the appearances of decalcifications, punched-out areas, erosions, and cartilage destruction. It is to be regretted, however, that the patients were not followed-up and examined in the course of the years during which the polyarthritis either progressed or became cured. Only in such a way can a correct description of all the minute details of the skeletal changes be obtained.

The study was in the main limited to the hands and finger joints. Changes in the toe joints, which according to the reviewer's experience (Acta radiol. 24 (1943)) often arise earlier than in the joints of the hands and fingers are not mentioned. Nor is there any word upon the juxta-articular periostitis which, for a short period, may appear in the initial stage of the disorder and affect particularly the toe joints.

Folke Knutsson.

THE MEASUREMENT OF BODY RADIOACTIVITY. Papers read at a Conference held at Leeds, 16—17 April 1956. 130 pp. British Journal of Radiology, Supplement No. 7, London 1957. 25 sh.

The advent of atomic energy work on a large scale, and the rapidly increasing production of radioactive isotopes, make it imperative to study in detail the radiation protection problems and to devise methods for the safe handling of large quantities of radioactive substances. For this purpose, measurements of body radioactivity are essential and must be carried out both as research projects for obtaining the most accurate and detailed information possible, and as large-scale programs to determine the body contamination with moderate accuracy but on a great number of individuals. It is gratifying to find in the present volume a report from a number of experts from different countries of the various methods in use. These include ionization chamber and scintillation methods, the relative merits of which are discussed for different problems. Attempts have been made to determine the total body burden either by measuring the gamma radiation emitted from the body or by analyzing the urine and faeces. Discriminator methods sometimes make it possible to identify certain isotopes, such as Cs 137, while the radon method measures Ra 226, excluding all others. Track autoradiography and analysis of tissues ashes are also used. In close relation to the main subject, several workers report on measurements of activity in drinking water and foodstuffs.

In view of the important character of the matter discussed in this supplement and the good picture given of the present state of the subject, it deserves a wide circulation.

Sven Benner.

DIE GESUNDE UND DIE KRANKE WIRBELSÄULE IN RÖNTGENBILD UND KLINIK. Von Georg Schmorl (†), bearbeitet von H. Junghanns. 4. erweiterte Aufl. 330 Seiten, 419 zum Teil farb. Abb. Georg Thieme Verlag, Stuttgart 1957. DM 86.—.

The second edition of this book, published in 1951, was reviewed in Acta Radiologica 1952 (Vol. 38, p. 165). The present issue constitutes the fourth edition. It is more extensive than the earlier one, this also applying to the illustrations; the diagrams have been further improved, and the bibliography has been increased from 30 to 40 pages.

The presentation is characterised by the consideration and inclusion of works published in recent years. The book is thus considerably improved since attention is devoted to recent progress within the field of the subject matter treated.

Folke Knutsson.

BOOKS RECEIVED

We acknowledge with thanks under this heading books received for review, which we trust will be regarded as a sufficient mark of appreciation of the courtesy of the sender. The reviews of selected items will appear as soon as opportunity affords.

PHYSICS IN MEDICINE AND BIOLOGY. Vol. 1, No. 1. (July 1956.) Taylor & Francis Ltd., London 1956.

LE DIAGNOSTIC DU CANCER D'ESTOMAC À LA PÉRIODE UTILE. Par René A. Gutmann. G. Doin & Cie., Paris 1956.

DIAGNOSTICS PNEUMOLOGIQUES. Par A. P. Jamion. G. Doin et Cie., Paris 1956.

THE HEAD AND NECK IN ROENTGEN DIAGNOSIS. 2nd Edition. By Eugene P. Pendergrass, J. Parsons Schaeffer, and Philip J. Hodes. Volume I. Charles C. Thomas, Springfield, Ill., 1956.

RECUEIL PÉRIODIQUE DE L'ENCYCLOPÉDIE MÉDICO-CHIRURGICALE. 5—6. Cahier spécialisé de radiodiagnostic. (Tome II.) Éditions Techniques, S. A., Paris 1956.

ACTIONS CHIMIQUES ET BIOLOGIQUES DES RADIATIONS. Deuxième série. Collection dirigée par M. Haissinsky. Masson et Cie., Paris 1956.

RADIOLOGICAL DIAGNOSIS OF BRONCHIECTASIS. By C. B. A. J. Puiljaert. H. E. Stenfert Kroese, N.V., Leiden 1957.

I QUADRI RADIOLOGICI DELLE GASTRITI, con la collaborazione del prof. Luigi Oliva. Relazione al LVII Congresso della Società Italiana di Medicina Interna, Milano Ottobre 1956. Ditta Luigi Pozza, Roma 1956.

STUDIO CLINICO-RADIOLOGICA DEGLI ESITI DELL'ASCESSO POLOMONARE. Degli Francesco Santagati, Mardo Calsi e Giancarlo Rivolta. Istituto Psichiatrici Provinciali di Milano, 1956.

RÖNTGENDIAGNOSTIK. Ergebnisse 1952—1956. Von H. R. Schinz, R. Glauner und E. Uehlinger. Georg Thieme, Stuttgart 1957.

YEAR BOOK OF RADIOLOGY. Edited by J. F. Floyd, F. J. Hodges, H. W. Jacoz and M. M. Kligerman. Year Book Publishers, Chicago 1957.

INTESTIN GRÊLE COLON-RECTUM. Éd. par Guy Albot et F. Poilleux. Masson et Cie., Paris 1956.

RECTOSCOPIE SIGMOÏDOSCOPIE. Par R. Bensaude. Troisième édition entièrement refaite par P. Hillemand, R. Cottan, A. Lambling et A. Bensaude. Masson et Cie., Paris 1956.

GUIDE TECHNIQUE ET TOPOGRAPHIQUE D'EXPLORATION BRONCHOLOGIQUE. Par Jean Ivannou. Masson et Cie., Paris 1956.

KURVEN UND TABELLEN FÜR DIE STRAHLENTHERAPIE. Von Felix Wachsmann und Alexander Dimotsis. S. Hirzel Verlag, Stuttgart 1957.

PROGRESS IN RADIOBIOLOGY. Proceedings of the Fourth International Conference on Radiobiology held in Cambridge 14th—17th August 1955. Ed. by Joseph S. Mitchell, Barbara E. Holmes and Cyril L. Smith. Olivier and Boyd, Edinburgh 1956.

DIE HÜFTNAHEN FEMUROSTEOTOMIEN UNTER BERÜCKSICHTIGUNG DER FORM, FUNKTION UND BEANSPRUCHUNG DES HÜFTGELENKES. Von Maurice Edmond Müller. Georg Thieme, Stuttgart 1957.

DIE PROGNOSE DER WIRBELSÄULENLEIDEN. Eine berufsprophylaktische Betrachtung. Von J. E. W. Brocher. Georg Thieme, Stuttgart 1957.

RETROPNEUMOPERITONEUM UND PNEUMOMEDIASTINUM. Von U. Cocchi. Georg Thieme, Stuttgart 1957.

GRUNDLAGEN FÜR DIE MESSUNG DER STRÖMUNGSGESCHWINDIGKEIT DES BLUTES MITTELS EINER RÖNTGENKYMOGRAPHISCHEN MESSMETHODE. Von W. Güntert und E. A. Zimmer. S. Karger A.G., Basel 1957.

INTERNATIONAL CONGRESS OF GASTROENTEROLOGY. Fifth meeting of L'Association des Sociétés Européennes et Méditerranéennes de Gastro-Entérologie, London, July 18—21, 1956. Reprint from Gastro-enterologia, Vol. 83 (1956): 3—5. S. Karger A.G., Basel 1957.

MANUAL OF RADIATION THERAPY. By K. Wilhelm Stenstrom. Charles C. Thomas, Springfield, Ill., 1957.

CLINICAL USE OF RADIOISOTOPES. A manual of technique. By T. Fields and L. Seed. Year Book Publishers, Chicago 1957.

DOES NOT CIRCULATE

UNIVERSITY OF MICHIGAN
AUG 1 1957
MEDICAL LIBRARY

ACTA RADIOLOGICA

CONDITA A GÖSTA FORSSELL

EDITA IUSSU SOCIETATUM RADIOLOGICARUM
DANIAE, FENNIAE, NORVEGIAE ET SUECIAE

Editor ERIK LINDGREN, Stockholm / *Editor adiuvans* OLLE OLSSON, Lund

Redactores

Dania: P. Flemming Möller, Köbenhavn; C. Krebs, Århus
Fennia: G. Jansson, Helsingfors; S. Mustakallio, Helsingfors
Norvegia: T. Dale, Oslo; J. Frimann-Dahl, Oslo
Suecia: S. Hultberg, Stockholm; F. Knutsson, Upsala

INDEX

Orbitography with water-soluble contrast media. By *G. Lombardi* 417
Orbital pneumography. By *Torstein I. Bertelsen* and *Olaf Petersen* . . . 426
Arterial 'spasm' in peripheral arteriography using the catheter method. By *Ingmar Wickbom* and *Osborne Bartley* 433
Arterial spasm caused by puncture and catheterization. An arteriographic study of patients not suffering from arterial disease. By *Åke Lindbom* . . 449
Electrokymographic observations in myxoma of the left atrium. By *Olle Marions* and *Per Ödman* 461
A modified catheter for percutaneous angiography. By *Gunnar Tornvall* . 470
On renal damage due to aortography and its prevention by renal tests. With reports of five cases of severe renal damage. By *Nils P. G. Edling* and *C. G. Helander* 473
The excretion of thorium and thorium daughters after Thorotrast administration. By *J. B. Hursh, L. T. Steadman, W. B. Looney* and *M. Colodzin* 481
Book reviews 499

VOL. 47 JUNE 1957 Fasc. 6

ACTA RADIOLOGICA

EDITORIAL NOTICE

ACTA RADIOLOGICA publishes original papers relating to medical radiology and nuclear medicine. The articles are printed in English, French or German according to the wishes of the author. Contributions from all countries are accepted but priority is given to those from Scandinavian sources. Papers are published on the clear understanding that they are contributed exclusively to Acta Radiologica. They are subject to editorial revision and the right is reserved to introduce such changes as may be necessary to make the contributions conform to the editorial standards but Acta Radiologica does not hold itself responsible for any statements made or opinions expressed by authors. Contributions should be as concise as possible. Papers of more than 24 pages, including space for figures and tables, cannot be accepted for publication without special permission from the Editor. More extensive articles may be published as supplements at the author's own expense. These are not subject to editorial revision. Contributions from Denmark, Finland and Norway should be forwarded to the Sub-Editors of the respective countries, others direct to the Editorial Secretary, Acta Radiologica, Stockholm 2, Sweden.

Contributions must be typewritten with double spacing (at least 1 cm between each line) and adequate margins; a short summary should be included with each. All typescripts should bear the name and full address of the contributor. A copy should always be retained by the author so that it may be available in the event of the origin being lost in transit. Alterations to print are costly and, with the exception of small corrections, will be charged to the author. Footnotes should be avoided as far as possible, since they break the reading of the text and are expensive.

Illustrations and tabular material should be unmounted and attached to the typescript in an individual cover. Numbering should be indicated in pencil lightly on the back and never appear on the front. The illustrations must be provided with suitable short legends and so worded that they are comprehensible without reference to the text. These legends should be typewritten on a separate sheet and not under the respective figures. Care should be taken that the illustrations only show the necessary details and essential features. Drawings and charts for reproduction should be in *black* (never in blue). The Editor reserves the right to reduce the size of illustrations as considered appropriate.

A bibliography must be added and the references should be arranged in alphabetical order of the author's name followed by his initials, full title of the paper and name of the journal — abbreviated according to *Fishbein: Medical Writing* or the *Quarterly Cumulative Index Medicus*. The volume number, year and number of first page of article should follow. Reference to books and monographs should indicate the author, the title, the edition, the name and city of the publisher, and the year of publication.

Example:

TILLINGER, K. G.: Papillary cystadenolymphoma. Acta radiol. 28 (1947), 241.

CAFFEY, J.: Pediatric X-Ray Diagnosis. Second Edition. The Year Book Publishers, Chicago 1950.

Fifty reprints will be presented to the author or divided among joint-authors. Additional reprints may be purchased at cost price but the necessary order must be given when the proof is returned.

Annual subscription rate 70 Sw. Kr. (plus 6 Sw. Kr. postage outside Scandinavia) payable in advance. Two volumes, each of 6 numbers appear annually. Single copies 7 Sw. Kr. (plus postage Sw. Kr. 1:—). The subscription will be considered automatically renewed if not cancelled at the latest 10 days before the publication of a new volume.

All communications in regard to advertising, subscriptions, change of address, etc., should be sent to Acta Radiologica, Stockholm 2, Sweden.

KUNGL. BOKTR. STHLM 1957

the elema

bi-plane film changer

gidlund system

for angiocardiography
angiography
aortography

for simultaneous exposures in two planes,
horizontal plane 12" × 14"
vertical plane 12" × 12"

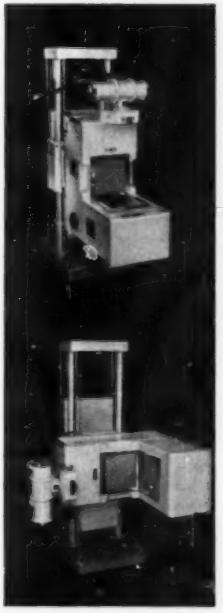
picture frequency variable
from 1 in 10 seconds
up to 8 per second, or
if preferred up to

12 exposures per second

consult us whether the X-ray unit in your department is suitable

we can also supply

X-ray units
high pressure syringes
catheters
electrocardiographs
electromanometers
oximeters
roll film processing units
viewing boxes etc., etc.



our high power X-ray units with electronic contactors and automatic control are especially suitable for use with the film changer

for further information write to

ELEMA INDUSTRIVÄGEN 23, STOCKHOLM • SOLNA SWEDEN

LIPIODOL

40% - 20% - 10%

The genuine iodised poppyseed oil

Bronchography
Hysterosalpingography
Myelography
Uretrograpi
etc...

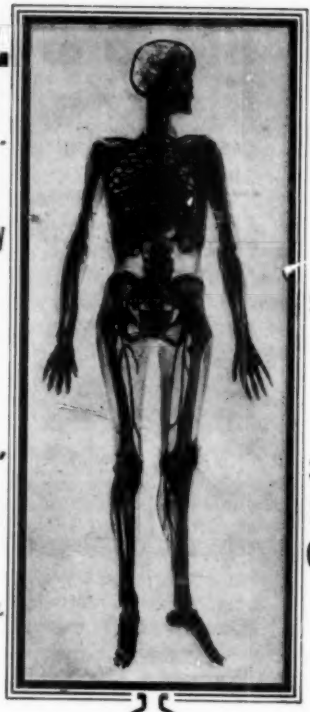
★

LIPIODOL "F"

(FLUID)

40% iodine

Seven times more fluid than LIPIODOL



NÉO-TÉNÉBRYL

(Brand of DIODONE)

70% solution, 20 cm³ amp.

Angiocardiography
Aortography

★

50% solution, 20 cm³ amp.

Excretion Urography
Arteriography

★

35% solution, 20 cm³ amp.

Excretion Urography
Cerebral Arteriography
Venography

LABORATOIRES ANDRÉ GUERBET ET Cie

22, Rue du Landy - SAINT-OUEN (PARIS) Seine - FRANCE

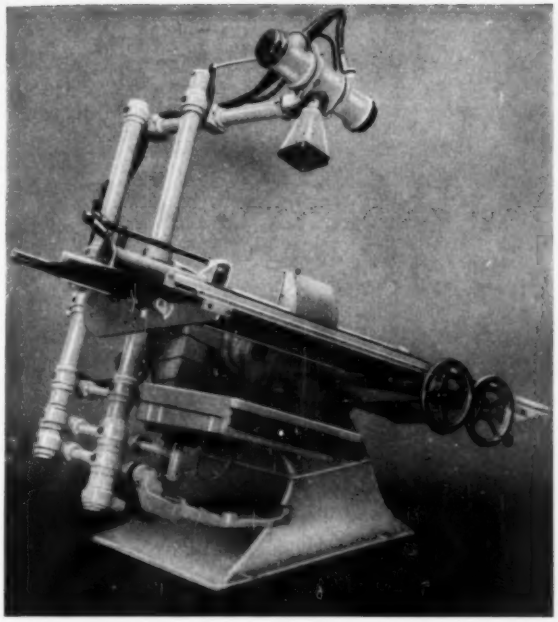
"Pioneers in the field of iodised Contrast Media"

LIPIODOL SULFANILAMIDE

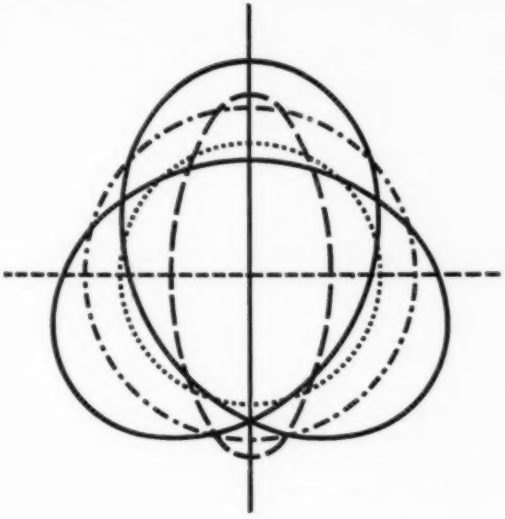
FOR BRONCHOGRAPHY

★ RAPID ELIMINATION
★ NO ALVEOLAR FILLING
★ NO TOXIC SIDE-REACTIONS

THE POLYTOME



EDICHA · PARIS



THE POLYTOME of SANS & PORCHER, a universal apparatus for sectional radiography, combines the following advantages:

ALL POSITIONS of the patient.

Four different obscuring movements giving different thicknesses of cut.

Straight line, maximum angle of section 60°.

Two circles, angles of section 29° & 36°.

Ellipse, angle of section 40°.

Hypocycloid, angle of section 48°.

Orientation of the obscuring movement selected.

Constant enlargement.

Oblique sections.

Utilisation for *standard radiographies.*

THE POLYTOME is fitted with the new automatic rotating antidiffusion grid.

G. MASSIOT *et* C^ie - 37 bis, Rue de Belfort, COURBEVOIE (Seine) FRANCE

Cable address : TEUGIDAR COURBEVOIE-FRANCE.
Telephone : DEFENSE 45-50.

Binding cases for

ACTA RADIOLOGICA

On application we will be pleased to forward substantial binding cases in discreet greybrown cloth with two spine labels printed in gold.

Price Sw. Kr. 6:— per case; incl. binding Sw. Kr. 20:—.

EXCERPTA MEDICA

The International Medical Abstract Service published in English and covering the whole field of Clinical and Experimental Medicine

RADIOLOGY

SECTION XIV

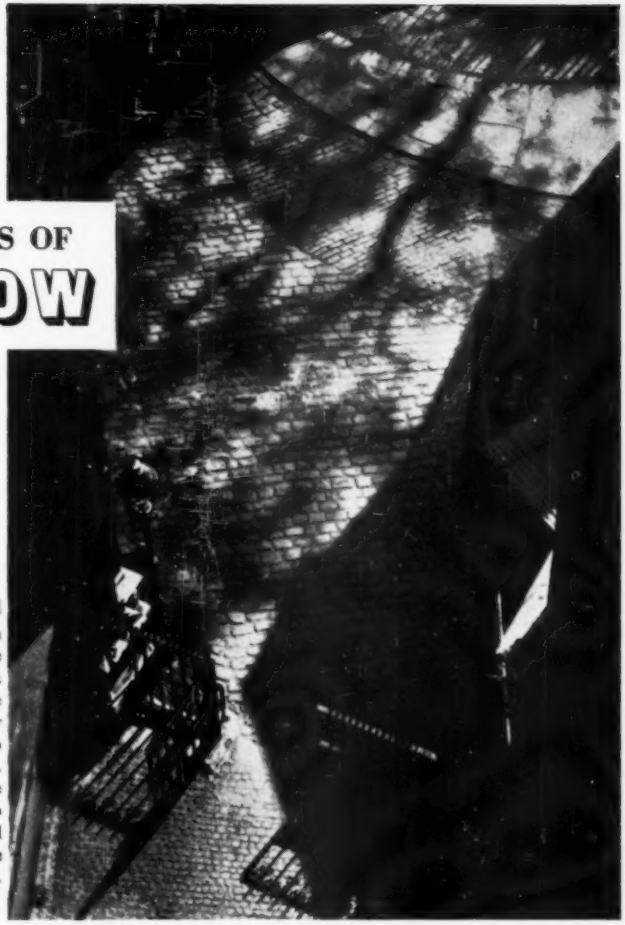
CONTENTS: In common with experimental sections, attention is paid in the choice of abstracts to fundamental and technical scientific details. Radiological diagnosis as well as radiological therapy is considered. Physiotherapy in all its various forms is included, in addition to strictly radiological subjects. Experimental science, covering the biological implications of radiology and its allied fields, can also be studied in this section.

The British Journal of Radiology.
" . . . The serious student of both diagnostic and therapeutic radiology will find this publication essential for keeping abreast of the literature because, indeed, it is impossible to conceive of any other way of doing so. The editors, publishers and abstractors, are to be heartily congratulated on the scope, manner of publication, and quality of the Journal . . . "

The subscription rate is £4. 8—s. per yearly volume of approximately 600 pages, including an index classified both by author and subject. Write for a prospectus or specimen copy.

Sole Distributors in all principal countries of the world.

SUBTLETIES OF SHADOW



FINE SHADES and distinctions seldom count so much as in the interpretation of a radiograph...and seldom are they more *consistently* achieved than with Glaxo radiological contrast media. From this range the preparation best suited to your individual requirements can be nicely selected.

DIONOSIL AQUEOUS
DIONOSIL OILY
For bronchography
(vials of 20 cc. and 100 cc.)

DIONOSIL POWDER
For bronchography
*(*for increasing viscosity of suspensions if desired: *bottles of 2 gm.)*

MYODIL
For myelography and ventriculography
3 cc. ampoules: boxes of 3

PYELECTAN
For intravenous pyelography and venography
20 cc. ampoules: boxes of 1 and 5

PYELECTAN *RETROGRADE*
For retrograde pyelography *10 cc. ampoules*

PYELOSIL
'35' and '50'—for excretion pyelography
42.5%—primarily for cerebral angiography
'70'—for angiocardiography.
All in ampoules of 20 cc.;
70% also in ampoules of 50 cc.

THE ABOVE NAMES ARE ALL REGISTERED TRADE MARKS

GLAXO LABORATORIES LIMITED • GREENFORD • MIDDLESEX • ENGLAND
Subsidiary Companies and Agents in most countries.

HAVE YOU SUBSCRIBED TO

ACTA RADIOLOGICA?

Founded 1921 by GÖSTA FORSSELL

ACTA RADIOLOGICA, published by the Radiological Societies of Denmark, Finland, Norway and Sweden, contain original articles on medical radiology and nuclear medicine, in English, French or German, every article being furthermore supplemented with summaries in these three languages. Each volume contains about 500 pages published in six numbers and is richly illustrated. So far, 47 volumes and 150 supplementary volumes have been published.

Subscription rate per volume: 55 Sw. Kr.; postage outside Scandinavia: 5 Sw. Kr. additional. (Thus annuat subscription rate: 76 Sw. Kr.)

EDITOR:

ERIK LINDGREN

NO RADIOLOGIST CAN GET ALONG WITHOUT

ACTA RADIOLOGICA

Subscriptions to *Acta Radiologica, Stockholm 2* (Sweden) or through the usual agents.

Acta Chirurgica Scandinavica

Editor: JOHN HELLSTRÖM, Stockholm.

Editorial Board: in Denmark N. BLIXENKRONE-MØLLER, E. DAHL-IVERSEN, E. HUSFELDT; in Finland A. R. KLOSSNER, F. LANGENSKIÖLD, V. SEIRO; in Norway H. G. GADE, H. FR. HARBITZ, C. SEMB; in Iceland G. THORODDSEN; in Sweden O. HULTÉN, PH. SANDBLOM, R. ROMANUS. Subscription: 40 Sw. Kr; abroad 45 Sw. Kr. Address: Tryckerigatan 2, Stockholm 2.

Acta Dermato-Venereologica

Editor: SVEN HELLERSTRÖM, Stockholm

Editorial Staff: in America H. GOODMAN, D. M. PILLSBURY, M. SULZBERGER; in Denmark H. HAXTHAUSEN; in England A. GRAY; in Finland T. I. PUTKONEN; in France L. M. PAUTRIER; in Germany A. MARCHIONINI; in Holland H. W. SIEMENS: in Norway N. DANBOLT; in Sweden G. HAGERMAN, S. HELLERSTRÖM, Å. NILZÉN, G. SEEBERG, N. THYRESSON in Switzerland G. MIESCHER. Subscription: 50 Sw. Kr. Address: Karolinska Sjukhuset, Stockholm 60.

Acta Medica Scandinavica

Editor: I. HOLMGREN, Stockholm.

Editorial Board: in Denmark H. I. BING, KNUD BRØCHNER-MORTENSEN, C. HOLTEN, EGGERT MÖLLER, ERIK WARBURG; in Finland BERTEL VON BONSDORFF, PEKKA BRUMMER, PENTTI I. HALONEN, WILLIAM KERPPOLA, F. SALTZMAN, I. VARTIAINEN; in Iceland S. SAMUELSSON; in Norway OLAV HANSSEN, CARL MÜLLER, P. A. OWREN, H. A. SALVESEN, HANS JACOB USTVEDT; in Sweden ERIK ASK-UPMARK, I. HOLMGREN, HENRIK LAGERLÖF, HAQVIN MALMROS, MARTIN ODIN, NANNA SVARTZ, JAN WALDENSTRÖM, ERIK WASSÉN, LARS WERKÖ; in The Netherlands J. G. G. BORST, F. S. P. VAN BUCHEM, P. FORMIJNE, C. D. DE LANGEN, J. MULDER, A. QUERIDO. Subscription: 45 Sw. Kr. per volume. In the Scandinavian countries and in Holland 40 Sw. Kr. Address: Stockholm K.

Acta Obstetricia et Gynecologica Scandinavica

Editor: AXEL WESTMAN, Stockholm 60

Redactores: E. RYDBERG, Copenhagen; E. A. BJÖRKENHEIM, Helsingfors; A. SUNDE, Oslo; A. WESTMAN, Stockholm — Annual subscription (1 volume): Sw. crowns 45:— (including postage) for Scandinavia, Finland, and Iceland, and Swed. Kr. 50:— (including pastage) for foreign countries. Single copies are Swed. Kr. 15:— postpaid. Editorial Office: Karolinska Sjukhuset, Stockholm 60.

Acta Oto-Laryngologica

Editor: PAUL FRENCKNER, Stockholm.

Co-Editor: Torsten Skoog.

Concilium Editorium: G. Dohlman, C.-A. Hamberger, Lennart Holmgren, C. O. Nylèn.

Editorial Office: Askrikegatan 3, Stockholm Ö.

Business Office: Box 47, Uppsala, Sweden.

Subscription: Sw. Cr. 60.00 (or $ 12.00), supplements included.

Acta Paediatrica

Editor: A. WALLGREN, Stockholm. Editor adiuvans; B. VAHLQUIST, Uppsala.

Editorial Board: in Denmark BENT ANDERSEN, OLUF ANDERSEN, P. PLUM; in Finland. P. HEINIÖ, V. RANTASALO, C.-E. RÄIHÄ, T. SALMI, ARVO YLPPÖ; in Holland S. VAN CREVELD, J. VAN LOOKEREN CAMPAGNE, J. P. SLOOFF; in Norway R. RINVIK, LEIF SALOMONSEN, L. STOLTENBERG, A. SUNDAL; in Sweden C. GYLLENSWÄRD, J. LIND, N. MALMBERG, STURE SIWE, WILH. WERNSTEDT, R. ZETTERSTRÖM. Subscription: 50 Sw. Kr. Address: Karolinska Sjukhuset, Stockholm 60.

Acta Physiologica Scandinavica

Editor G. LILJESTRAND, Stockholm.

Editorial Board: in Denmark F. BUCHTHAL; in Finland Y. REENPÄÄ; in Norway R. NICOLAYSEN. Subscription: 45 Sw. Kr. per vol. (3 vol. per year). Address: Karolinska Institutet Stockholm 60.

Acta Radiologica

Editor: ERIK LINDGREN, Stockholm. Editor adiuvans: OLLE OLSSON, Lund.

Redactores: in Denmark P. FLEMMING MÖLLER, C. KREBS; in Finland G. JANSSON, S. MUSTAKALLIO; in Norway T. DALE, J. FRIMANN-DAHL; in Sweden S. HULTBERG, F. KNUTSSON. Subscription: 35 Sw. Kr. per volume (2 volumes per year), postage 3 Sw. Kr. additional for non-Scandinavian countries. Address: Tryckerigatan 2, Stockholm 2.

Acta Societatis Medicorum Upsaliensis

Upsala Läkareförenings Förhandlingar. Editor: GUNNAR BLIX.

Subscription: 20 Sw. Kr. Address: Almqvist & Wiksells Boktryckeri AB, Uppsala.

Subscriptions, manuscripts and advertisements for the above Acta should be forwarded under the names of the respective Acta, addresses as above.

CAWO

CAWO-Simultan-Mehrschichtaufnahmen-Komposition

für Simultan-Schichtaufnahmen bewährt durch ihre Vorteile:

- bis zu sieben schwärzungsgleiche, zeichenscharfe Schichtbilder mit gutem Kontrast durch sieben Folienkombinationen
- Anwendungsbereich ab 60–125 kV
- Verwendbar für die gebräuchlichen Blenden
- Frei wählbare Schichtabstände von Aufnahme zu Aufnahme

CAWO-Röntgenverstärkungsfolien

für Film- und Papieraufnahmen gewährleisten beste Bildgüte in Zeichenschärfe und Kontrast

CAWO-Röntgenleuchtschirme

zeigen höchste Zeichenschärfe, kräftigen Kontrast, vorzügliche Helligkeit

CAWO-Röntgenpapier

mit sehr guter Detailwiedergabe, kräftigen Kontrast, hoher Empfindlichkeit mit breitem Belichtungsspielraum

Fordern Sie bitte unsere Prospekte und Angebote an

CAWO

Photochemische Fabrik GmbH

Schrobenhausen/Obb.

Ensamförsäljare för Sverige

SVENSKA AKTIEBOLAGET PHILIPS RÖNTGENAVDELNINGEN

STOCKHOLM GÖTEBORG MALMÖ

The finest X-Ray Tubes still cost less than in 1949

Continuous research, advanced manufacturing techniques and modern equipment—these are the factors that make Mullard X-ray tubes second to none for performance and reliability.

And despite rising prices, Mullard X-ray tubes still cost less than in 1949.

This is a good reason why it will pay you to specify Mullard when next you order X-ray tubes.

Mullard

X-RAY DIVISION

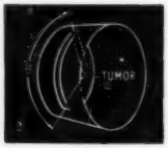
MULLARD LTD., X-RAY DIVISION, NEW ROAD, MITCHAM JUNCTION, SURREY, ENGLAND

TELEGRAMS EMVALCO SOUPHONE
LONDON ENGLAND

MXR. 501

ROTATIONAL · PENDULUM · PENDULUM CONVERGENCE CROSSFIRE · SINGLE-FIELD

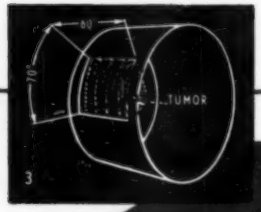
ALL ADVANCED DEEP-THERAPY TECHNIQUES NOW INCORPORATED IN ONE UNIVERSAL EQUIPMENT



1 Rotational irradiation. One band with 330° Rotation.

2 Pendulum irradiation.

3 Pendulum convergence irradiation. In this technique, the focus of the X-ray tube describes a scanning path over the patient, covering the area in a zig-zag motion.

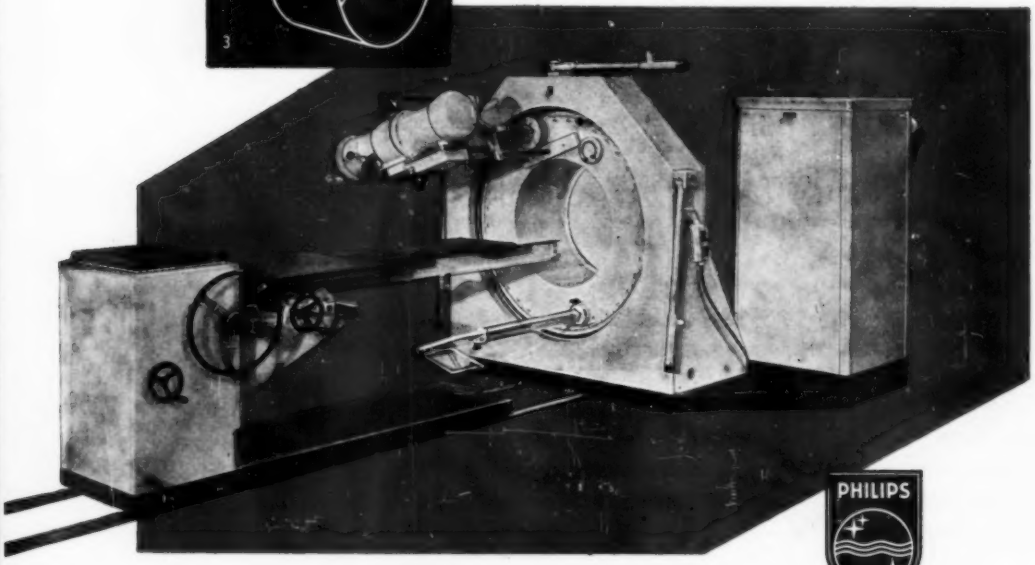


250 kV-25mA
TU-1

This 250 kV, 25 mA moving-beam equipment is the most modern and versatile interpretation of advanced therapy techniques. It is designed to spread the incident dose over a large skin area and thus safely achieve a high relative depth dose.

- *Covers every moving-beam technique with the patient immobilized in a recumbent position.*
- *Highly sensitive, accurate adjustments for all the various movements.*
- *250 kV/25 mA — 150 kV/25 mA generator (constant potential).*
- *Automatic stabilization of high voltage and tube current.*
- *Continuous monitoring of the X-ray dose.*

This outstanding design is a typical example of Philips leadership in X-ray manufacturing. Descriptive literature will be sent on request.



PHILIPS

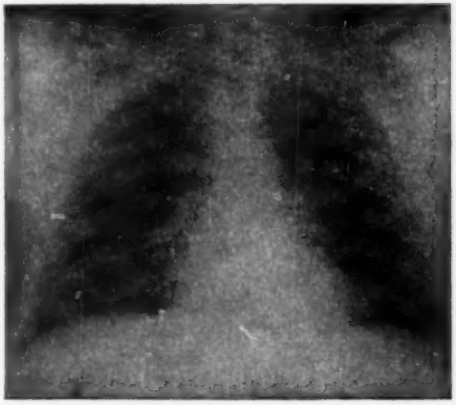
FOR FURTHER INFORMATION PLEASE APPLY TO THE PHILIPS ORGANISATION IN YOUR COUNTRY OR TO PHILIPS, X-RAY AND MEDICAL APPARATUS DIVISION, EINDHOVEN, NETHERLANDS.

CONSISTENT

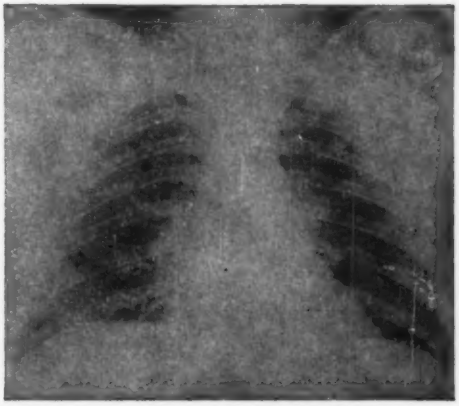
Radiographic Film Densities and Subject Contrast

. . . are assured only with MACHLETT low-drop valves

Compare These Radiographs



With MACHLETT Low-Drop Valve Tubes . . . consistent film densities consistent subject contrast



Conventional High-Drop Valve Tubes . . . variation in film densities variation in subject contrast

BOTH Radiographs taken under identical conditions, with valves operating at 10% below rated filament voltage.*

All thoriated-tungsten filament valve tubes are not alike— Only Machlett offers modern valve tubes with the catenary long-life thoriated-tungsten filament (patent pending), plus the assurance of consistent radiographic results provided by low-drop design.

Consult Your X-Ray Dealer for Information About Machlett Low-Drop Thoriated-Tungsten Filament Valve Tube Replacements.

*Changes in filament voltages are always present in varying degree—due to line voltage fluctuation and to lowered voltage caused by operating load of equipment.

Radiographs taken at 57 PKV, 500 MA; 1/30 Sec., 72".

MACHLETT

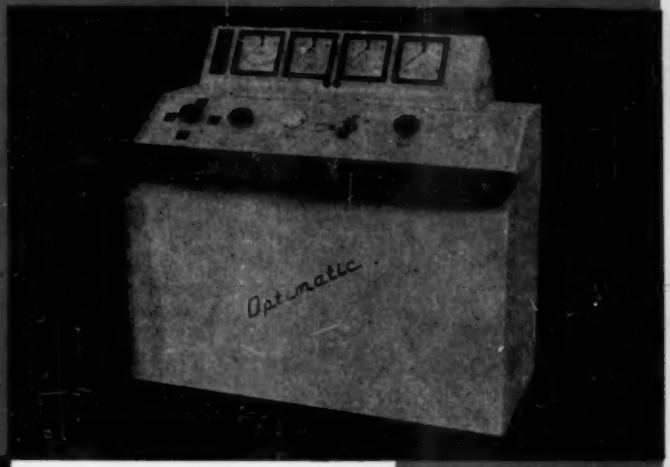
MACHLETT LABORATORIES, INC.
Springdale, Connecticut

HIGH VOLTAGE TECHNIQUE | 150 KVP

WITH OUR

SKANDIA OPTIMATIC

4-VALVE X-RAY APPARATUS WITH ELECTRONIC CONTACTOR.



OUTPUT:	1000 mA at 65 kVp 300 mA at 150 kVp
AUTOMATIC	filament stabilization.
2 SETTINGS ONLY:	mAs and kV.
mAs-COMPUTER:	2,5—1000 mAs in 27 steps.
TRUE kV INDICATION:	50—150 kV
EXPOSURE TIMES:	0.003—8.0 sec.
SWITCHING FREQUENCY:	up to 8 exposures per sec. with option of 25 per second if required.
ACCOMMODATION	up to 4 double focus R.A. tubes.
SPECIAL ACCESSORY UNIT	can be supplied for simultaneous operation of two X-ray tubes for 2-plane angiography.

FULL INFORMATION WILL BE SENT ON REQUEST

ELEMA

INDUSTRIVÄGEN 31, STOCKHOLM - SOLNA SWEDEN

5994